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Plastics IN BUILDING

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Plastics

IN BUILDING

The uses, past and present, and the potentialities of plastics in building as reported at a conference conducted by the Building Research Institute, October 27 and 28, 1954, at the Chamber of Commerce of the United States in Washington, D. C.

Published
April 1955

BUILDING RESEARCH INSTITUTE
Division of Engineering and Industrial Research
National Academy of Sciences • National Research Council
Washington, D. C.

$5.00

ACKNOWLEDGEMENTS

The Building Research Institute wishes to express its appreciation to the speakers and moderators of the conference on Plastics in Building for their fine cooperation during the course of the program and for the high technical level of the material presented. Special thanks are due to The Society of the Plastics Industry, Inc., the Manufacturing Chemists' Association, Inc., and the members of the Committee for the Plastics in Building Conference, for their aid in obtaining speakers and moderators and in helping to define the areas to be covered by the conference. Also, Mr. Harry N. Huntzicker, Vice President in Charge of Research at U.S. Gypsum Company, is thanked for his work as General Chairman of the conference.

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2101 Constitution Avenue • Washington 25, D. C.

NAS—NRC Publication 337
Library of Congress Catalogue Number: 55-60009

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FOREWORD

IN ALMOST every aspect of building the architect, the builder, and the contractor are hearing about products made of plastics, or of other building materials combined with plastics, for their consideration in design and construction. Since the performance of any material or product is of constant concern to the building professions, it is natural for them to have many questions about any new materials available for building purposes.

While some plastic materials have been used for many years by the building industry, the tremendous development of the plastics industry since World War II has focused attention on its possibilities in the construction field. The plastics industry believes that, used correctly, its products have a place in the great building market. Plastics industry technologists want the construction industry to have a true account of the qualifications and potentialities of their materials for appropriate uses in building.

The contents of this book comprise the views of many of the foremost authorities in the plastics, chemical and building industries concerning the past, present and future uses of plastics in building.

These views were first presented at a conference on Plastics in Building conducted by the Building Research Institute in Washington, D. C., October 27 and 28, 1954. Also included are selected questions as asked by attendants at this conference, and the answers given by the authoritative speakers.

The Plastics in Building conference was sponsored by The Society of the Plastics Industry, Inc., the Manufacturing Chemists' Association, Inc., and the Building Research Advisory Board. It was the second conference conducted by the Building Research Institute to bring together technical people from all sectors of the building industry to discuss the application of a specific material to building. (The first was on porcelain enamel.) Such conferences are entirely technical and objective in nature and have for their purpose the stimulation of progress in the development of building materials and products.

PRINCIPAL SPEAKERS AT THE CONFERENCE

Max Abramovitz

John S. Berkson

Johan A. Bjorksten

Raymond F. Boyer

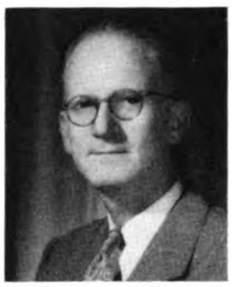
George Clark

Edward B. Cooper

Albert G. H. Dietz

Harry N. Huntzicker

R. N. Kennedy



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Tyler S. Rogers

Raymond B. Seymour

Robert Fitch Smith

A. T. Waidelich

Joseph S. Whitaker

SYNOPSES OF CONFERENCE PAPERS

PLASTICS USED IN BUILDING CONSTRUCTION

By E. B. Cooper (E. I. du Pont de Nemours and Co., Inc.)

THE general properties of plastics—translucency, formability, and that fact that when they are reinforced their strength approaches that of steel—provide new degrees of freedom in architectural design. Because there are many chemical types of plastics with significant differences among them, it is important to select the plastic which is best suited to the specific purpose desired. One of the more important facts about plastics is their ability to move under stress and, when the stress is removed, to return to their original position. It is important to know that under a sustained stress the plastic will deform — called "creep" — and when the stress is removed the plastic will return to its original form slowly.

There are two broad classes of plastics: thermosetting and thermoplastic. Plastics made from thermosetting resins undergo a chemical change when they are molded; those made from thermoplastic resins simply soften when heated to the fabrication temperature and undergo no chemical change.

Thermosetting plastics are outstanding for rigidity, relatively low creep under load, and for solvent resistance. The principal ones are phenol formaldehyde, urea formaldehyde, melamine formaldehyde, and polyesters.

There are many types of thermoplastics. The oldest is cellulose nitrate, discovered more than a century ago and first used for billiard balls. Cellulose acetate is tough and strong, takes outdoor exposure, and is available in sheets, rods, and tubes. Cellulose acetate butyrate is outstanding for toughness, impact strength, dimensional stability and ease of fabrication. Ethyl cellulose is unusually tough and dimensionally stable even at very low temperatures. Polystyrene is a rigid, clear plastic in its unmodified state. Used with fibrous fillers, or by blending with polymers, its impact strength is greatly improved. Acrylic plastics are famed for their clearness and strength; the "blisters" on aircraft are familiar to all. Vinyl chloride plastics are used structurally in rigid sheets and as pipes. Crystalline thermoplastics are strong and tough; some have excellent chemical resistance and some can be used at very high temperatures. Polyethylene is tough, is used widely in packaging, wire covering, extruded pipes, industrial tanks, tank liners and containers.

Plastic foams are used for thermal insulation and core material for lightweight structural members and panels. Polyvinyl butyral is used as the interlayer for safety glass.

PHYSICAL AND ENGINEERING PROPERTIES OF PLASTICS

By Albert G. H. Dietz (Massachusetts Institute of Technology)

THE range of the physical properties of plastics is as great as the range of metals and is much greater than those of either timber or concrete. Depending on the formulations and reinforcing materials, plastics can be extremely weak or extremely strong. To a degree, plastics behave in an elastic manner. Their plastic behavior—creep or flow—depends on the load or stress applied, and the rate and duration of application. Many plastics exhibit a time-dependent plastic behavior: the plastic behavior is greater at higher temperatures; as the temperature drops they become stiffer and stronger, eventually become brittle at 0° F. or lower. When desiring to use plastics—especially thermoplastics—temperature, stress, and duration of load must be considered if designing for strength.

Fillers and plasticizers greatly modify the properties of plastics. They can make a brittle, hard-to-mold plastics like phenolic resin which is rather costly, more moldable and less expensive to use. Electrical properties, heat resistance, toughness, strength, flame resistance, stability, and shrinkage, can be improved through the use of fillers and plasticizers.

Laminates and reinforced plastics—plastics combined with sheet or fibrous materials to produce a composite—offer high strength in large sized units. Such reinforced plastics are used for wall coverings, table tops and counter fronts, for example, where strength, toughness and resistance to marring, water, alcohol, and common solvents give a low maintenance cost.

The variety of reinforcing materials available gives the engineering designer wide latitude in tailoring materials to his requirements.

Sandwich construction—two thin, hard, strong facings combined with a relatively thick, lightweight, weak core, offer lightness, strength and rigidity. Many combinations of materials can be employed. Plastics can be used for structural and decorative facings. Cores can be made of foamed plastics or honeycombs or resin-impregnated paper.

The thermal expansion of plastics is high and must be kept in mind. Thermal conductivity is low; plastics are better insulators than metals, though few approach the heat insulating value of wood perpendicular to the grain. Corrosion resistance is one of the most attractive features of plastics. At least one resists nearly all corrosive conditions found in building.

All plastics can be destroyed by fire; some burn easily and some may be self-extinguishing depending on the base, filler, and plasticizer. Some have outstanding temperature resistance.

Weather resistance at present is an uncertain factor, particularly over a long period, due to the relative newness of the industry; there are, however, some fine records of use from such as the acrylics—used as aircraft glazing and in outdoor applications—for periods ranging up to twenty years. Loss of gloss and a dulling of color can be expected from some plastics exposed to weather. Reliable data is needed on weather tests since the life of buildings is usually thought of in terms of twenty to fifty years. Trends in building construction and design will have a major effect on the use of plastics. Two are important at present: shop-fabrication of building units, and the use of large clear spans with no internal support.

EVALUATING PLASTICS FOR BUILDING APPLICATIONS

By Tyler S. Rogers (Owens-Corning Fiberglas Corporation)

TWO properties must be taken into consideration to evaluate effectively the uses of plastics in building. They are the molding and fabrication processes, and the economic relationship of plastics to similar products made of other materials.

The final plastic product is influenced by fillers used, temperatures and pressures employed in the molding operations, workmanship, and even humidity. Molding methods are illustrated and described in this paper.

Cost is important in many ways. Sometimes, plastics may be used because no other method will make the part as economically. However, in most cases a variety of factors is involved. The initial costs—materials, dies, molds, etc—may be high but may be offset by rapid production. The use for which the plastic part is intended, physical and chemical factors, even decorative use, may all be important considerations. All or several may offset higher costs.

The factors favoring plastics for building use include formability, colorability, durability, chemical resistance, low thermal transmission, clarity, electrical characteristics, and physical strength. Some limiting properties are elastic behavior, stiffness, thermal expansion, heat tolerance and weathering.

LIGHT-TRANSMITTING PANELS

By John S. Berkson (Alsynite Corporation of America)

WEATHER resistance of fiberglass reinforced plastics in the light-transmitting field is not all that could be desired at present. However, it has greatly improved in recent years. Fiberglass reinforced plastics are now used in the awning field. It offers the advantages of an awning—reduces the light—and overcomes the disadvantage of darkness by having a high light diffusion value. Corregated fiberglass material offers interior daylighting, uniformally diffused, and can be attractive and decorative through various applications and colors that may be architecturally engineered.

In cost comparisons, things to consider are: fiberglass needs no special framing; it can be sawed, nailed, screwed and molded into place; it is lightweight; it is shatterproof; is a high diffusing agent; and is decorative. These light-transmitting panels have an unlimited range of colors. The tensile strength is about 15,000 psi; flexural strength, about 24,000 psi. As with all plastics, its correct application is important.

GLAZING AND INTERIOR ILLUMINATION

By O. L. Pierson (Rohm & Haas Company)

LIGHT-TRANSMITTING plastics are also used for skylights, luminous ceilings, facades, and lighting fixtures, as well as glazing. The water-white transparency of the basic acrylic plastic permits a full spectrum of colors from neutral gray for glare control to diffusing, translucent colors. Special compositions transmit more ultraviolet light than normal glass glazing. In cast sheet form the material is available in sizes up to 8 by 10 feet and from 1/16 inch up in thickness.

Vinyls are not recommended for long-term outdoor use. They are extremely tough and so can be used in very thin sections, and are self-extinguishing. Thin sheets are usually corrugated to provide rigidity. Vinyl is transparent but is normally used as a white translucent for diffusion of artificial lighting.

Polyesters, with fiberglass reinforcement, have great strength and can be made in a variety of custom shapes and sizes. They have good weather resistance. They are widely used as corrugated panels and are translucent due to the fiberglass reinforcement.

PLASTIC THERMAL INSULATIONS AND VAPOR SEALS

By R. N. Kennedy (The Dow Chemical Company)

BASICALLY, plastics are a poor conductor of heat. Therefore, in their expanded form, they meet accepted values for thermal insulation. Expander plastics, in many cases, are also resistant to accumulations of water and ice, are odorless, and will not decay or rot. They have a high strength-weight ratio.

Most expanded plastics due to high cost—a few because of low strength or resistance to water—have not been acceptable to the building industry as insulation. There is one exception: expanded polystyrene. It meets insulation requirements and has been used in many ways including low-temperature insulation for freezer and cooler spaces in refrigerated trucks, railroad cars, ships and domestic refrigerators.

Expanded polystyrene was first used as a combination moisture barrier and insulation, and plaster base, in masonry block houses about eight years ago. It is an excellent roof insulation, though special techniques are required for built-up roofs. It is also being used as a core material in sandwich construction.

Low-cost polyethylene film is being used as a vapor barrier in walls, under floor slabs, and in crawl spaces in dwellings.

PLASTICS IN STRUCTURAL PANELS

By A. T. Waidelich (The Austin Company)

IT IS only recently that plastics have been introduced to the production of large prefabricated units, made up of two or more components. The larger the quantity that is produced, of course, the more economical is the product. If this is to be done, designers must depart from traditional methods for the small home. Much of the skeletal framework can be eliminated and the walls, partitions and roof can then be made up of relatively few prefabricated structural panels.

Sandwich panels have been made with thin, strong exterior faces and a thicker, lightweight core. Veneer, plywood and aluminum facings have been used.

Expanded polystyrene forms a good bond with concrete. Interior plaster can be applied directly to boards of expanded polystyrene plastic.

At present, plastics for the structural framing of large buildings is not competitive in cost with steel or concrete nor do they yet have the needed strength. They are being used as wall panels and partitions for some large structures, however, and are supported with steel framing.

Since curves pose no problem to plastic shapes, they can and are being used for concrete forms which are difficult to fashion from wood.

SURFACING AND DECORATIVE USES OF PLASTICS IN BUILDING

By Hiram McCann (MODERN PLASTICS)

THERE are three basic types of resiliant vinyl floor covering: flexible, semiflexible, and rigid. The author states that first vinyl flooring was laid in 1933 and is still in use and nearly as good as new. The paper tells about 13 manufacturers vinyl flooring products.

Under decorative uses the author tells of the two main categories of decorative thermoset laminates, gives a number of trade names, their qualities and uses. In regard to polystyrene wall tile, builders are urged to follow National Bureau of Standards specifications. Spray coating with vinyl is discussed for its decorative effect and durability.

PLASTIC PIPING

By J. S. Whitaker (The Bakelite Company)

PLASTIC piping is being used for water, sewerage, gas, and electric distribution. Pipe fittings are made of plastics. Inherent advantages are light weight, corrosion resistance and handling ease.

Plastics most widely used for piping are acrylonitrile copolymer blends, cellulose acetate butyrate, polyethylene, polyvinyl chloride (PVC), polyvinylidene chloride (Saran), and combinations of glass fiber with thermosetting resins. Each material has properties suitable for certain uses. PVC and Saran are self-extinguishing; polyethylene is the lightest and most flexible; the glass-reinforced materials have a low thermal coefficient and closely match the coefficient of steel.

Polyethylene is popular because of its flexibility and chemical inertness. Cellulose acetate butyrate is semirigid and can be handled in long coils; it is available as a clear transparent pipe. Acrylonitrile copolymer blends are rigid and weigh about one-seventh as much as steel; it is made in standard and extra-heavy wall iron-pipe sizes and is usually threaded, as are its fitting and adapters. It can be solvent welded.

Being light in weight, blastic pipe requires less support than metal pipe. For exterior disposal lines, it can be assembled above ground and buried in very narrow trenches. The flexible pipe need not have a level-bottom ditch for it will conform to uneven surfaces.

Plastic pipe is now being made in standard wall, heavy wall, and light wall sizes for domestic sewer lines, water lines and other plumbing purposes.

PLASTIC DUCTS AND CONDUITS

By Raymond B. Seymour (Atlas Mineral Products Company)

MANY types of plastic materials have been employed for ducts and conduits in the past 15 years; they have been used extensively in Europe but, until recently, had a limited use in the United States. Wide selections of plastic materials now are available but the user must pay close attention to physical and chemical properties in order to select the right material. This paper gives the physical and chemical properties of the different kinds of plastics for ducts and conduits. There is a section on application data with a list of successful applications to date. The writer stresses that plastics cannot replace all materials for all purposes. Big advantages are corrosion resistance, light weight, and good flow characteristics—few materials can compete with plastics in these instances if the operating temperature for the duct work is below 150° F.

STANDARDS FOR PLASTIC PRODUCTS

By Gordon M. Kline (National Bureau of Standards)

PLASTICS are a relatively new material in the construction field and as a result the process of standardization is an evolving one. There are two kinds of standards, static and dynamic. The former provides quantitative and reproducible measures for well-defined masses or constants; the latter serves as a yardstick of quality in a diverse and changing system. Dynamic standards are greatly needed to help provide a medium to guide producers and consumers of a new material for building in its utilization and development. The continually growing "standard of living" in the United States is a dynamic standard. The author tells of some published standards for plastics and explains the National Bureau of Standards Plastics Section is accomplishing for plastics standards. There is a reference list of published standards.

BUILDING CODE REGULATION OF PLASTIC BUILDING MATERIALS

By F. J. Rarig (Rohm & Haas Company)

BUILDING code regulations represent a very potent exercise of police power over a $40 billion building industry. The demand for uniformity in regulations is very insistant. Among the organizations working to this end are the Building Officials Conference of America, Pacific Coast Building Conference, Southern Building Congress. American Standards Association, National Board of Fire Underwriters, Underwriters Laboratories, and the National Bureau of Standards. The evaluation and approval of specific building materials, the inspection and regulation of them, is secured by codes based on performance standards. The overlapping of enforcement agencies, the duplication of study and work by each, different administrative determinations, duplication of licensing fees, are problems that need attention.

As new materials, like plastics, are introduced into the building field, code officials must be supplied with standards factors for them. The plastics and building industry can work together to help the code officials and others to get this information. The author tells of the basic problems that arose in attempting to get plastic materials accepted by local code administrators. Plastics had to be defined, data set up for building inspectors, and "enabling legislation" proposed which would allow the building officials to approve the standardized plastics for specific uses, as well as set up limitations on the uses.

The author concludes that the regulatory pattern can be established only when the problem has been defined by the demand for the use of material. This is a possible reason why the regulatory program has not been able to keep pace with commercial aspirations

THE FUTURE OF PLASTICS IN BUILDING

By Johan A. Bjorksten (Bjorksten Research Laboratories, Inc.)

THIS is an exploratory, realistic, and highly imaginative paper on building in plastics. The author discusses the advantages of using plastics: high strength to weight ratio; translucency; continuity of structure; and fire resistance.

He suggests mass production techniques which can minimize labor costs. Though costs are often high, he points out that special uses may justify plastics and gives an example of adding a second story to a building which, structurally, was built for only one story. He explains how plastics could be used successfully for underground construction since they overcome difficulties inherent to most waterproofing compounds and materials presently used by the building industry. He concludes with an imaginative discussion about plastic floating structures placed on the tropical seas and used to raise produce for the evergrowing and hungry world.

The round-table session which follows this talk is both imaginative and practical, including as it does talks on successful uses of plastics in construction and talks on some future uses which are now getting beyond the laboratory stage.

Part I

AN INTRODUCTION TO PLASTICS IN BUILDING

PLASTICS USED IN BUILDING CONSTRUCTION

By Edward B. Cooper*

E. I. du Pont de Nemours & Co., Inc.

I SHALL not attempt to describe all of the kinds of plastics which are now used in the building industry. Rather, I will discuss the general properties which make plastics useful materials for construction. Then, I will distinguish among the principal types of plastics according to their fields of application in the building industry. If my text serves as a useful background for the material which follows, I shall feel that its mission has been accomplished.

In this presentation, plastics will be designated by chemical type of resin, rather than by trademark or manufacturer. It should be understood that plastics, based on the same resin but formulated by different manufacturers, may differ widely in properties. The selection of a particular plastic for a specific use, therefore, should be made *after* consultation with the manufacturers.

Plastics are a relatively new class of construction. Designers, architects, and engineers are finding that some old problems in building construction can be solved through the use of plastics. Restaurant counters of laminated plastic and plastic floor tile are recognized for their beauty and durability under heavy service conditions. Skylights are formed from weather-resistant, transparent plastics to provide in one continuous surface the glazing, frame, and flashing. Plastic foams surpass cork as thermal insulation and are less restricted in size, shape and color. Plastics reinforced with glass fibers exhibit strengths approaching that of steel. These strength properties, coupled with translucency and formability, provide new degrees of freedom in architectural design.

There are many chemical types of plastics and many varieties within each chemical type. There are significant differences among the types and varieties of plastics. It is these differences which make one plastic superior to another for specific applications. There is one structural feature common to all plastics: They all contain resins which are composed of long, thread-like molecules (Figure 1.1.). The central backbone of these long molecules consists of hundreds, or thousands, of individual atoms. Within a solid plastic article the molecules are kinked, coiled, and thoroughly entangled. Figure 1.1 illustrates how such an entangled mass might appear if magnified many millions of times.

Plastics are useful as structural materials because of the way in which this snarl of long, coiled molecules accommodates itself to stresses. The tougher plastics absorb punishment by yielding to stresses and then by recovering their dimensions after stresses are removed. This accommodation to stress and subsequent recovery is thought to be accomplished by the motion of segments of the thread-like molecules. This ability to move under stress enables the segments to equalize local stress concentrations. At least, for small stresses there is no relative motion of entire molecules. The displaced segments return slowly to their original positions after stress is removed. This property is important when designing structures from plastics. It is significantly different from properties of other materials of construction.

Plastics often contain plasticizers which effect the motion of molecular segments. Polyvinyl butyral, for example, can be highly plasticized polymer, containing about 20 per cent of a plasticizer. This material is used as the interlayer in safety glass. Stretching a strip of polyvinyl butyral illustrates the characteristic mechanical behavior of plastic in a highly exaggerated fashion. If stretched 50 per cent and then released, the strip promptly snaps back to its original position. But, if it is held in its stretched position for several seconds, the strip snaps back only part way to its original position. It will slowly regain the balance of its deformation, however. This

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characteristic mechanical behavior should be recognized when designing structures using plastics. Because of it, plastics will slowly deform under sustained loads; we call this "creep." The plastics slowly will recover when the loads are removed.

I want to emphasize that this illustration is exaggerated. The large amount of plasticizer in polyvinyl butyral results in physical properties at room temperature which unplasticized resins possess only at elevated temperatures. Even plastics which are exceedingly strong and rigid at ordinary temperatures adapt themselves to bear high stresses in this way, however. The creep deformation of a rigid plastic under load may be only a fraction of one per cent in a long period. But when the stress is removed this tiny deformation slowly disappears.

Although all plastics contain these long, coiled and kinked molecules, there are vast differences in the freedom of internal motion among the various plastics. Some plastics have bulky side groups at regular intervals along the molecular backbone (Figure 1.2). These side groups, or "chains," interfere with the motion of molecular segments. Such plastics are hard and stiff. But molecules of certain other plastics, such as polyethylene, have an extremely regular arrangement of small groups or single atoms along their backbones (Figure 1.3). These molecules pack together in a regular manner. When they cool from a melt, the molecules form crystals in which segments of two or more molecules may be present. These crystals restrict the motion of molecular segments and profoundly affect the physical properties of the resulting plastic. Still other plastics contain molecules to which are attached groups capable of joining chemically with groups in other nearby molecules.

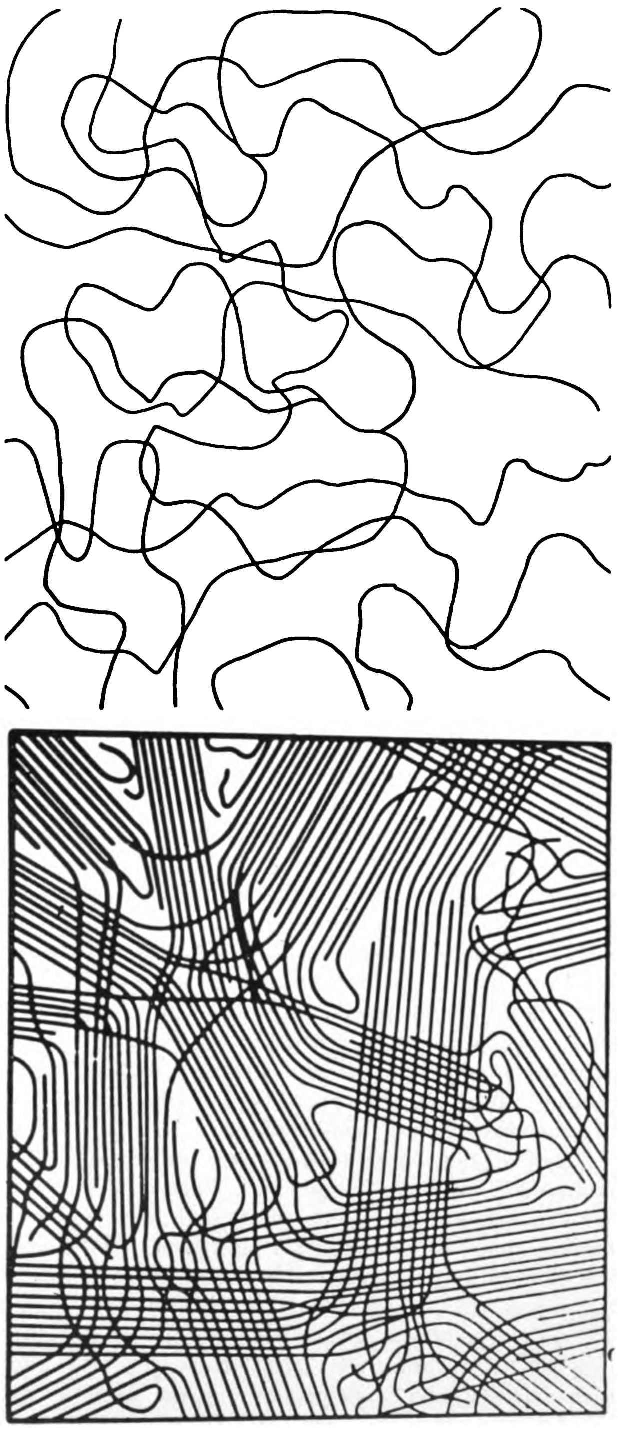

FIG. 1.1: Long thread-like molecule common to all plastics (upper), and patterns formed when two or more molecules associate (lower).

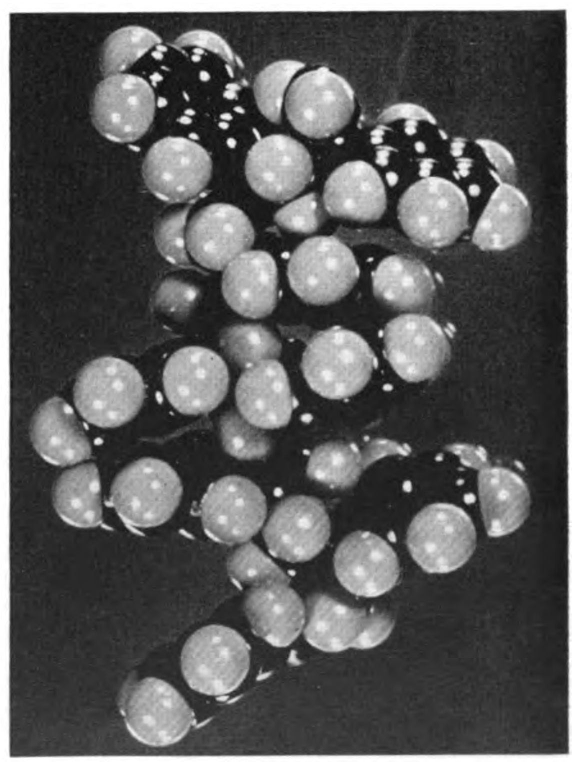

FIG. 1.2: Model of polymethylmethacrylate molecule

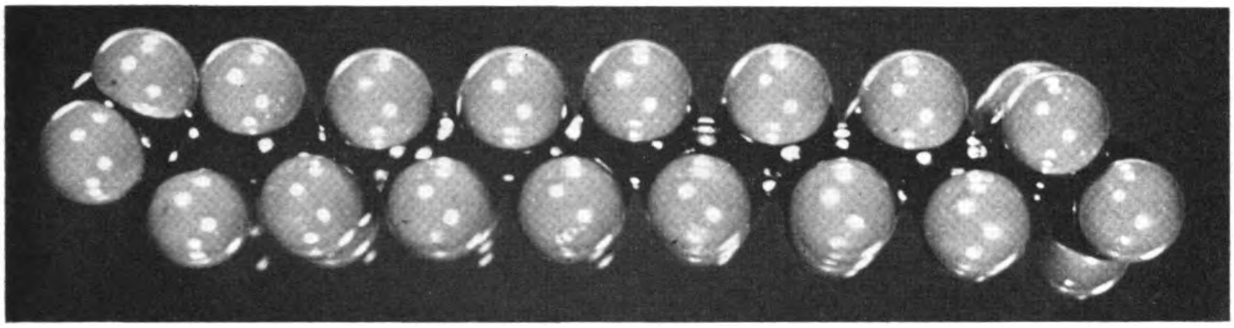

FIG. 1.3: Model of polyethylene molecule

These chemical cross-links tie the molecules together and also restrict the internal motion (Figure 1.4).

Rubbers, adhesives, protective finishes, and synthetic fibers are very closely related to plastics. The common GR-S rubber is a copolymer of butadiene and styrene. Blending polystyrene with GR-S rubber yields a tough plastic. Urea formaldehyde and phenol formaldehyde resins are used both as plastics and as adhesives. Cellulose nitrate resins are used in lacquers and in plastics. Nylon is used both as a synthetic fiber and as a tough, structural plastic.

CLASSIFICATION OF PLASTICS BY CHEMICAL STRUCTURE

Some commercial plastics contain only one type of chemical molecule. Many other plastics, however, contain more than one, either as a blend or mixture, or through direct chemical bonding. In addition to the molecular chains, many plastics contain fillers which strengthen or toughen the material. Plasticizers are frequently used to facilitate fabrication or to meet specific needs.

Thermosetting and Thermoplastic Resins: These are two broad classes of plastics—those made from thermosetting or thermoplastic resins. These names refer to the behavior of the plastics during fabrication. When thermosetting resins are molded they undergo a chemical change. Cross-links are formed between molecules, which make the plastic insoluble and infusible. The material leaving the mold, therefore is chemically different from that which enters the mold.

Thermoplastics, on the other hand, simply soften when heated to fabrication temperatures. No chemical change is involved and the material leaving the mold is identical chemically with that entering the mold. Thermoplastics can be held at elevated temperatures during fabrication, so they can be shaped by techniques not applicable to thermosetting plastics. These techniques include injection molding, melt extrusion, and the forming of articles from sheet material.

Thermosetting Plastics: Cross-linking of the molecules in thermosetting plastics imposes some limitation on the fabrication techniques that can be used, but this cross linkage contributes some valuable properties to the plastic. As a class, thermosetting plastics are outstanding for rigidity, for relatively low creep under load, and for solvent resistance. Such properties are of great importance in structural uses. Thermosetting plastics serve well in many load-bearing applications. The principal thermosetting plastics are phenol-formaldehyde, urea formaldehyde, melamine-formaldehyde, and polyesters.

Each of these types of plastic is modified by fillers selected to meet particular requirements. Fibrous fillers, for example, are used to enhance the impact

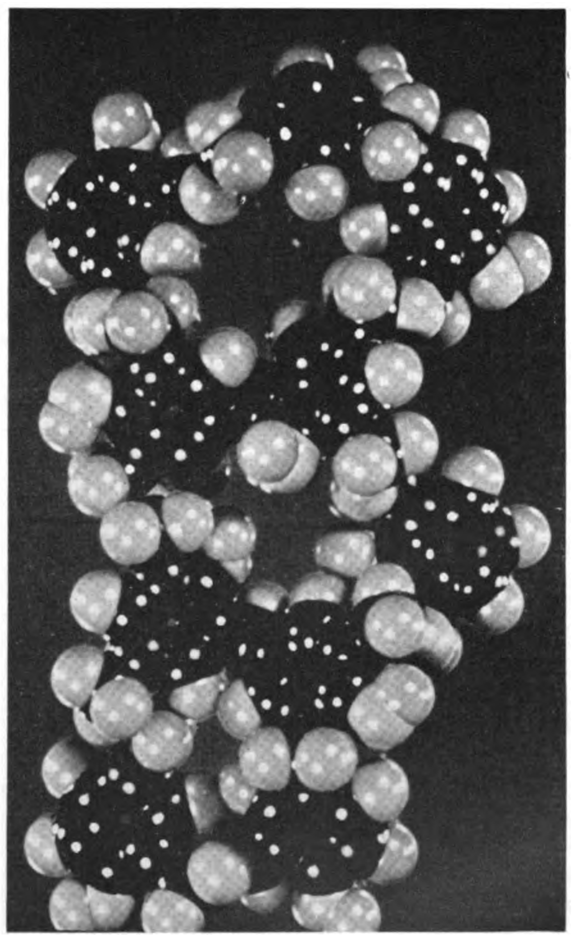

FIG. 1.4: Model of phenol formaldehyde resin

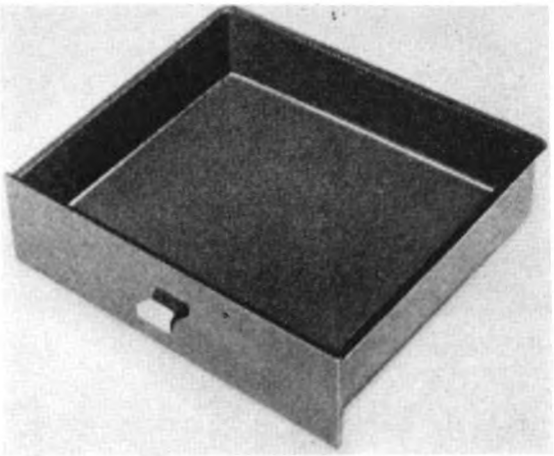

FIG. 1.5: Molded phenol formaldehyde resin

strength, while mineral fillers improve heat resistance and electrical properties. Through these modifications a very wide range of materials is made available to engineers and designers. The technical data book of the Manufacturing Chemists' Association lists detailed data for seven distinct types of melamine-formaldehyde molding powder and for 17 types of phenol-formaldehyde molding powder.

Phenol Formaldehyde Plastics: Phenol formaldehyde resins are used in very large quantities in molding powders and in laminated sheets, rods, and tubes. Molding powders are made from phenol formaldehydes combined with fillers such as wood flour, cotton flock, chopped paper, fabric, cord, asbestos, mica, or silica. Compression or transfer molding methods produce hard and rigid molded articles. These plastics withstand high temperatures, but are limited to dark colors. Large moldings such as television cabinets and washing machine agitators can be made readily. Small articles are molded in multi-cavity molds (Figure 1.5). Laminated phenol formaldehyde products include sheets, rods, and tubes, which are used primarily in the electrical industry as panels, housings, and switch parts.

Urea Formaldehyde Plastics: Urea formaldehyde plastics are usually filled with pure alpha cellulose, which permits an unlimited range of colors. Since the water absorption of these resins is relatively high, they are not recommended for uses involving continuous or intermittent exposure to water. These plastics are used in boxes, housings, electrical parts, and lighting fixtures (Figure 1.6).

Melamine Formaldehyde Plastics: These thermosetting plastics are distinguished for their rigidity, hardness, flame resistance, and low water absorption. Melamine formaldehyde plastics have many electrical uses. In addition, colorful and durable dishware is molded from this type plastic. Laminated melamine sheets provide durable surfaces for counter and table tops and for high grade wall panels.

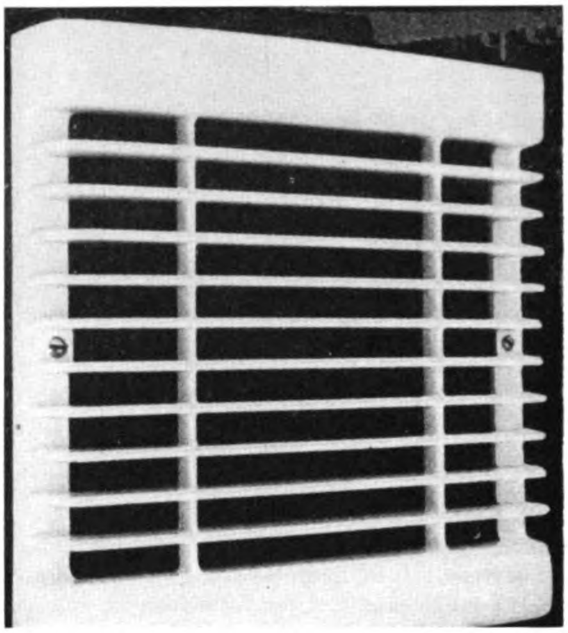

FIG. 1.6: Ventilator grille of molded urea formaldehyde resin

Polyester Plastics: It is noteworthy that this list of thermosetting plastics contains both one of the oldest—and one of the newest—synthetic plastics. Phenol formaldehyde plastics have been important as construction materials for nearly half a century. The commercial use of polyesters, on the other hand, began scarcely a decade ago. Polyesters are the principal resins used in the glass-fiber reinforced plastics structures stimulating so much popular interest. Fishing rods, boats, automobiles, furniture, washing machines, and translucent roof and wall panels are among the many successful products resulting from this marriage of fiber and resin.

The resins are usually supplied as liquids of low viscosity. They consist of polyester resins dispersed in a polymerizable monomer such as styrene. A catalyst is added just before the resin is applied to the glass fibers. The resin may be poured or sprayed on the reinforcing cloth or mat. The cross-linking, or curing reaction, requires only moderate temperatures and pressures, and is completed within a very few minutes.

THERMOPLASTICS

Cellulosics: A dozen or more chemical types of plastics have attained commercial stature. Several of these are based on cellulose.

Cellulose Nitrate: Cellulose nitrate is the oldest synthetic plastic. It was discovered nearly a century ago and was used as a material of construction for, of all things, billiard balls. This plastic is an exceedingly strong material, fabricated readily by sheet forming, by die cutting, and by machining tech-

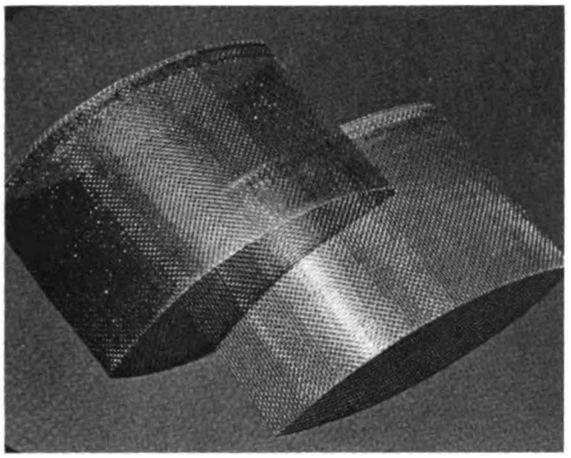

FIG. 1.7: Wire mesh reinforced cellulose acetate sheet

niques. The flammability of cellulose nitrate, however, has restricted its usefulness considerably. Compression and injection molding operations cannot be used. Although fire retardants containing chlorine and phosphates reduce the flammability, there is some accompanying loss in physical properties.

This tough thermoplastic has served many useful purposes, from ping pong balls to the interlayer material in automotive safety glass. Principal uses today include eye glass frames, fountain pen barrels, tool handles, and coverings for wood heels and toilet seats.

Cellulose Acetate: Developed as an improvement over cellulose nitrate with respect to flammability and outdoor exposure, cellulose acetate is a strong, tough, multipurpose thermoplastic. It is available in sheets, rods, and tubes, and in molding and extrusion compounds (Figure 1.7). To meet the needs of specific applications, manufacturers of cellulose acetate have varied its molecular structure, have introduced a wide range of fillers, and have used various plasticizer formulas. The technical date book of the Manufacturing Chemists' Association gives detailed data on the 13 types of cellulose acetate molding powders covered by the American Society for Testing Materials specifications.

Cellulose Acetate Butyrate: This cellulosic thermoplastic is outstanding for its toughness, impact strength, dimensional stability, and ease of fabrication. Typical applications are telephones, automobile steering wheels, radio housings, and pipes for irrigation and industrial uses. ASTM specifications describe 12 grades and types of cellulose acetate butyrate molding materials. Detailed data are given in the MCA Technical Data Book.

Ethyl Cellulose: Ethyl cellulose is unusually tough and dimensionally stable, even at exceedingly low temperatures. Typical applications include radio housings, vacuum cleaner parts, and tool handles.

Other Non-Crystalline Thermoplastics: Cellulosics are non-crystalline thermoplastics. Other principal non-crystalline thermoplastics include the styrene plastics, the acrylics, and vinyl chloride compounds.

Styrene Plastics: Plastics based wholly or partly on styrene are used in very large quantities. Unmodified polystyrene is rigid, clear, and colorless, and has outstanding electrical properties. Greatly improved impact strengths are possible by copolymerization, by blending with other polymers, and by the use of fibrous fillers. Other modifications also have improved the heat resistance of styrene plastics. Typical uses of this plastic include refrigerator door liners, transparent containers, toilet seats, automobile instrument panels, storage battery cases, and wall tile.

Acrylic Plastics: Used in the plastic "blisters" on military aircraft, acrylic plastics have gained wide recognition for their strength and clarity (Figure 1.8). The acrylics' outstanding resistance to weathering makes them useful for glazing applications in buildings and outdoor display signs. Molded acrylics are widely used in automobiles, as well as in radio and television parts. Acrylic plastics are commercially available in cast and extruded sheets and in powders for injection for compression molding, or for extrusion.

Vinyl Chloride Plastics: Used in very large quantities, these plastics are based on vinyl chloride alone or on vinyl chloride copolymerized with vinyl acetate. Rigid sheets and pipes of unplasticized polyvinyl chloride are now being used quite widely in this country for structural purposes. In Europe, however, vinyls have been used for these applications for many years. Plasticized vinyl chloride sheeting is widely used in upholstery, in luggage, and in rainwear. Phonograph records and floor tile are other important applications, although they require special formulations of plasticizers as fillers. The "mothballing" films used to protect inactive military equipment are produced by spraying water dispersions of vinyl chloride.

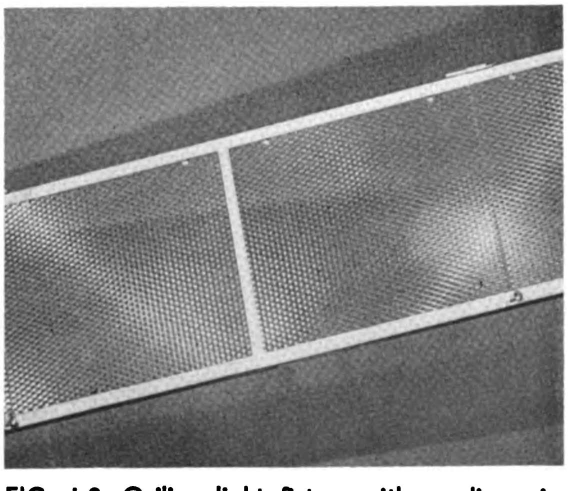

FIG. 1.8: Ceiling light fixture with acrylic resin

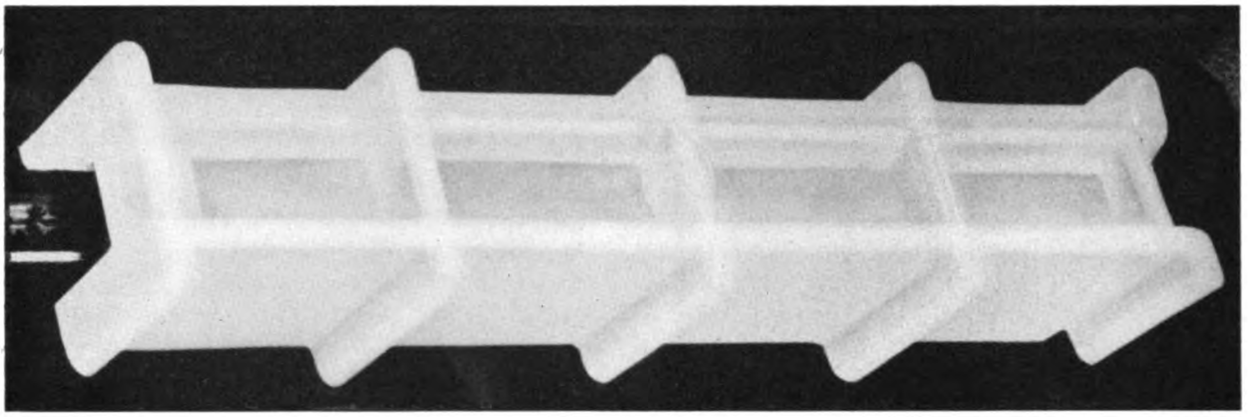

FIG. 1.9: An elevator gib made of molded nylon

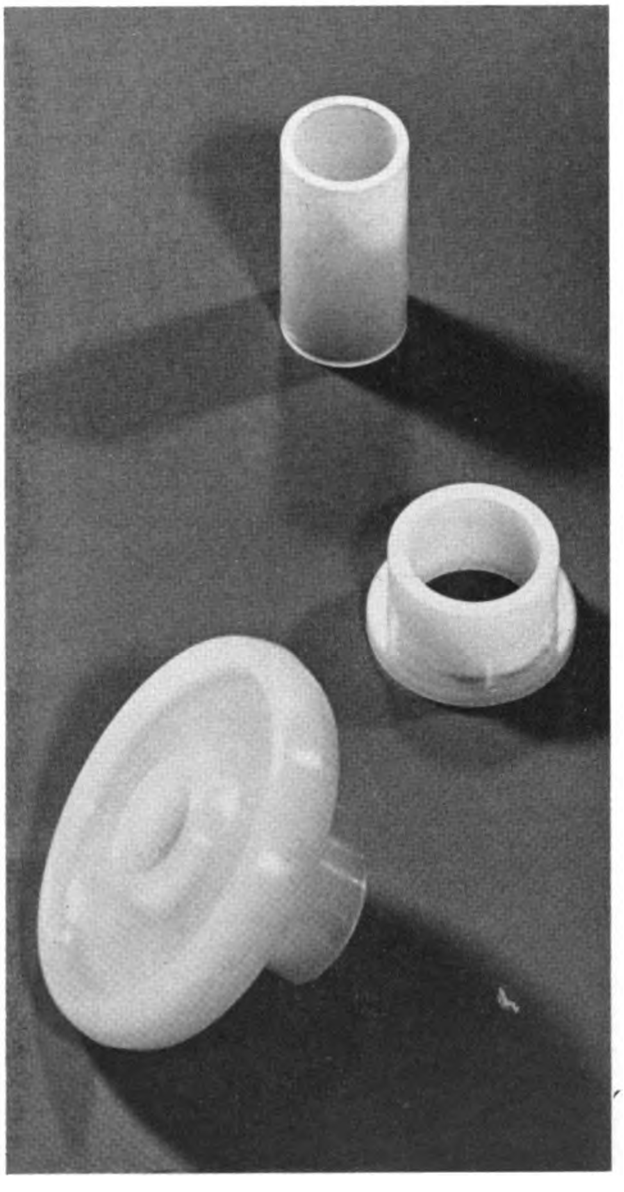

FIG. 1.10: Nylon garage door rollers and bearings

Crystalline Thermoplastics: Several commercially important thermoplastics are based on resins made up of molecules which become bound to each other through crystallization. Segments of the long polymer molecules become connected with segments of other polymer molecules in these crystallites. One molecule may participate in several crystallites. These structures melt when the plastics are heated to fabrication temperatures and the molecules can move freely. On cooling, crystallites reform and restrain molecular motion, much as the chemical cross-links do in thermosetting plastics.

As a class, the crystalline thermoplastics are strong and tough. Some can be used at very high temperatures and some have excellent chemical resistance. Since the crystallites scatter light, crystalline thermoplastics are transparent only in very thin sections. In thicker sections they are translucent.

Polyethylene: Polyethylene is a tough, crystalline thermoplastic resin which can be fabricated by all the usual techniques. Unsupported films are now widely used in the packaging field. Wire covering and extruded pipe, "squeeze" bottles, industrial containers, tanks and tank liners are among the important uses of polyethylene.

Recent publications have noted that some physical properties of certain thermoplastics are markedly affected by radiation from an atomic pile or from an electron accelerator. The physical properties of most thermoplastics are affected adversely by exposure to high energy radiation. A few thermoplastics, however, show desirable changes in certain physical properties after exposure to specific levels of radiation.

Considerable interest has been expressed in the changes in polyethylene resulting from exposure to high energy radiation. It holds its shape better under extremely low leads at elevated temperatures. It also is much more resistant to environmental stress cracking. When exposed to higher radiation levels, the stiffness begins to increase significantly, but the tensile strength and elongation decrease very rapidly, leading to brittle, fragile products.

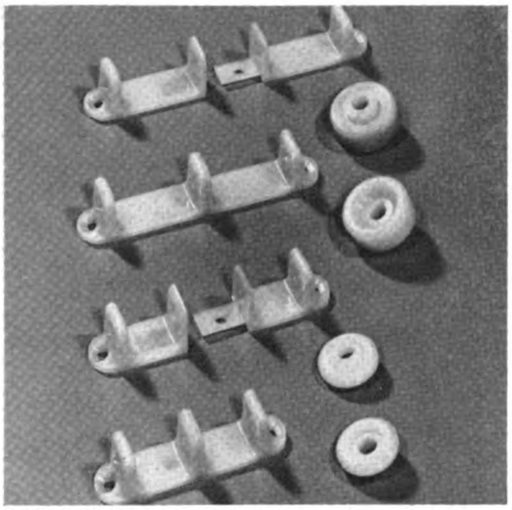

FIG. 1.11: Sliding door hardware of molded nylon

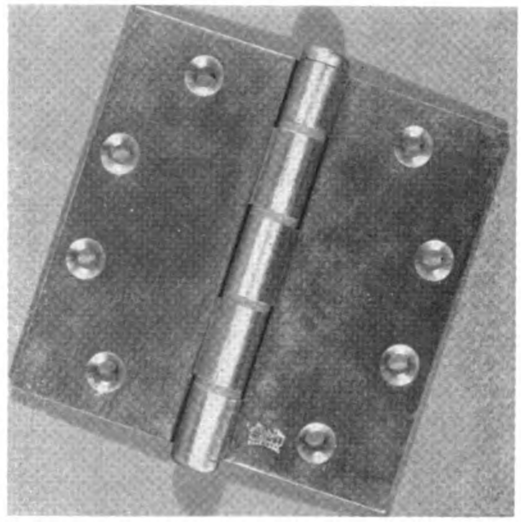

FIG. 1.12: Bearings in door hinge are molded nylon

Under high energy radiation, polyethylene molecules become joined together, or cross-linked. You will recall that in thermosetting compounds the large molecules are tied together as a result of a chemical reaction during fabrication. Polyethylene is normally a thermoplastic, but the free radicals formed under radiation cause bonds to form between the molecules. These reduce the freedom of motion of molecular segments.

Polytetrafluoroethylene: Polytetrafluoroethylene, a very high-melting thermoplastic resin, resists practically every chemical reagent, and is completely unaffected by weather. It also has outstanding electrical properties. Special techniques are required to mold or extrude this material, however. This plastic is available in sheets, rods, and tubes, as molding powder and in sheets reinforced with glass fiber. Typical applications are wire covering, tubing, and gaskets for use under extreme temperature, or in corrosive atmosphere.

Polyvinylidene Chloride: Polyvinylidene chloride is outstanding for its chemical resistance, low-moisture permeability, and weather resistance. It is particularly well known as a packaging film, as a fiber for outdoor furniture and automobile seat covers, and as window screen.

Polyamides: Nylon is an unusually tough, rigid, and heat-resistant polyamide plastic. Mechanical parts of molded nylon are becoming widely used in building construction, particularly as door and drawer rollers and as hinge and motor bearings.

Figures 1.9 through 1.12 illustrate some typical uses of these crystalline thermoplastics.

Plastic Foams and Films: Plastic foams are formed when gaseous blowing agents are released within viscous, molten plastic. These foams usually are very rigid if a rigid resin is used and very soft if a highly plasticized resin is used. They are used as thermal insulation and as the core material of light-weight structural members and panels.

One plastic serves the building industry solely as a film. It is polyvinyl butyral, the interlayer in safety glass discussed earlier. Fifteen thousandths of an inch of this tough transparent plastic reduces the frightfulness of automobile accidents. Polyvinyl butyral is now being used in other forms of glazing, particularly in laboratory hoods.

CLASSIFICATION OF PLASTICS BY SIGNIFICANT USES IN BUILDING

Piping and Valves for Corrosion Resistance—polyvinyl chloride, polyethylene, cellulose acetate butyrate, polyvinylidene chloride, styrene copolymers, polytetrafluoroethylene.

Surfaces for Counter Tops—melamine-formaldehyde.

Floor Tile—polyvinyl chloride and its copolymers.

Wall Tile and Transparent Bricks—polystyrene.

Glazing and Lighting Fixtures—acrylics, polystyrene, cellulose acetate butyrate.

Grilles, Radio and TV Cabinets, Furniture—phenol-formaldehyde, urea-formaldehyde, polyester laminates.

Refrigerator Parts, Door Liners, Etc.—polystyrene and copolymers, polyester laminates.

Translucent Roofing and Curtain Walls—polyester laminates.

Window Sreens, Webbing for Lawn Furniture—polyvinylidene chloride.

Rollers, Bearings for Doors and Drawers, Elevation Giles—polyamides.

Wire Insulation—polyvinyl chloride, polyethylene.

Flashing and Expansion Joints—polyvinyl chloride.

Extruded Moldings, Architectural Trim—polyvinyl chloride.

SUMMARY

In this discussion of plastics used in building, it is recognized that the characteristic mechanical properties of plastics are due to the long, thread-like molecules which are linked, coiled, and entangled. Deformation of plastics under load occurs when segments of these molecules move under applied stresses. When the stress is removed, these displaced segments tend to return to their original position.

Plastics exhibit a wide range of mechanical properties. The properties of plastics are modified profoundly by fillers which stiffen and reinforce and by plasticizers which can make a hard and rigid polymer soft and extensible.

In thermosetting resins molecules become cross-linked during fabrication. This cross-linking contributes desirable rigidity and insolubility but limits fabrication techniques. The entire plastic mass must be heated and formed within a short time.

Thermoplastics are classified into three groups of materials: cellulosics, other non-crystalline thermoplastics, and crystalline thermoplastics. Non-crystalline thermoplastics provide a tremendous range of physical properties. Molecular structures can be varied; copolymers and blends with other polymers can be made; fillers and plasticizers can be added. In the crystalline thermoplastics, the molecules are tied together by crystallites. These crystallites restrain the motion of molecular segments and thus improve rigidity and stability of the plastics.

This text has been limited to those plastics which have now reached considerable commercial importance. New materials, new fabrication, and new application techniques doubtless will result from the vigorous research and development efforts now in progress. However, it is not necessary to wait for these new developments. The present commercial plastics offer noteworthy combinations of strength, color, shape, durability and cost.

PHYSICAL AND ENGINEERING PROPERTIES OF PLASTICS

By Albert G. H. Dietz*

Massachusetts Institute of Technology

DR. E. B. COOPER has outlined the principal classes of plastics and has indicated their general physical properties as determined by their chemical structure. In this text, I will attempt to describe those physical and engineering properties of plastics which make them interesting for building. These same properties may, however, limit their usefulness. Principal trends will be indicated in building design and construction. From these trends, coupled with the properties of plastics, some conclusions can be drawn as to possible applications.

Plastics are already used in building in considerable quantities. The fact that this conference has been assembled indicates the lively interest of plastics manufacturers, engineers, builders, and architects in the construction potentialities of plastics.

One of the oldest uses of plastics in building is an adhesive. Plastics provide the completely waterproof glues for plywood and other waterproof glued construction. Plastics also have made possible better varnishes and lacquers, improved drying oils, and other finishes widely used today in buildings. Plastics combined with wood, paper, and fabrics provide building with superior qualities. Large quantities of plastics are used in flooring. Upholstery and wall coverings are made of tough sheets, coated fabrics, and woven plastics. Transparent and translucent plastics are used in schoolhouse windows and street lights where breakage and maintenance costs are high. They are used for skylights and illumination devices where their ready formability makes them especially adaptable. All of these applications came about because of certain physical properties and combinations of properties to be found in plastics.

PHYSICAL PROPERTIES

Dr. Cooper described the structure of plastics as a jumbled mass of long molecules, sometimes interconnected, sometimes semi-ordered or semi-crystalline. He also pointed out that the physical properties are a reflection of this structure. The range of properties of plastics, including laminates, within their own limits is as great as the range of metals, and is much greater than that of either concrete or timber. This is brought out in Figure 1.13 in which the ranges of

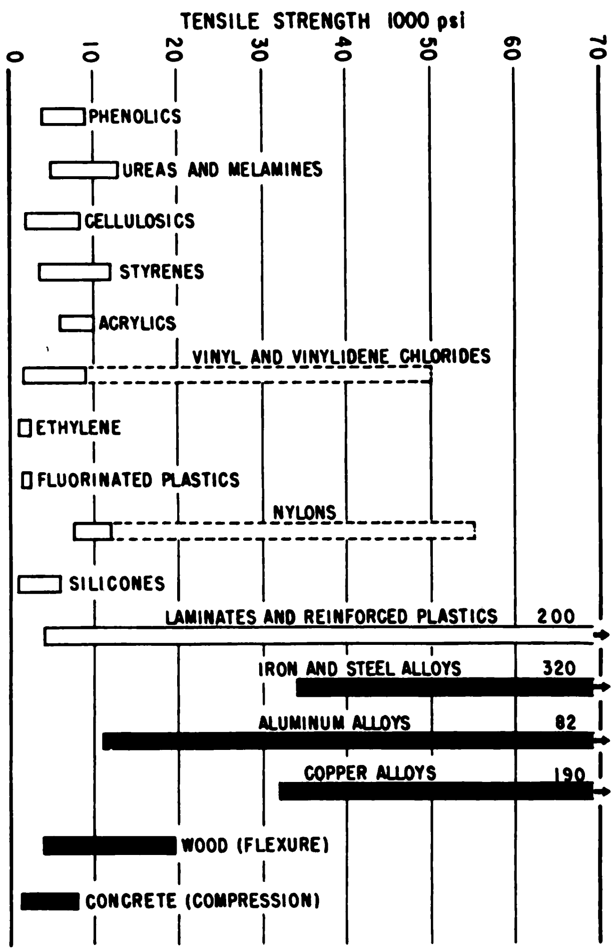

FIG. 1.13: Tensile Strength of Plastics and other materials

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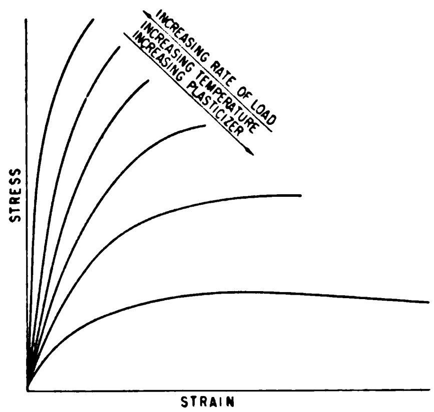

FIG. 1.14: Effect of Temperature Chart

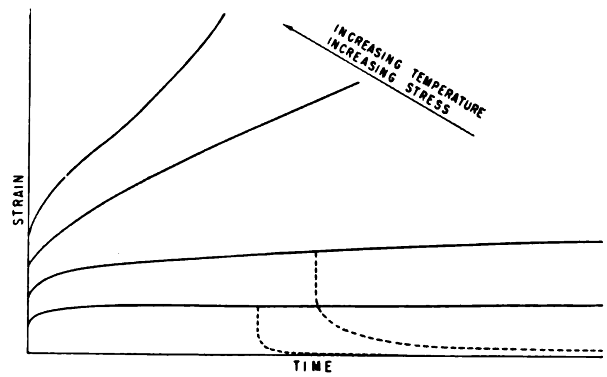

FIG. 1.15: Creep and Recovery Chart

tensile strengths of the principal classes of plastics, and of plastics-based laminates and reinforced plastics, are compared with iron and steel alloys, aluminum alloys, copper alloys, wood, and concrete. Depending upon the formulations and reinforcing materials employed, plastics may be extremely weak or extremely strong, with a range approximately 200 to one.

Elastic and Plastic Behavior: To some degree, plastics behave in an elastic manner; their deformation under load is directly proportional to the load. When the load is removed the deformation disappears. In engineering design, such materials as steel, concrete, and timber are assumed to behave elastically. As long as stresses are kept within limits, steel certainly behaves elastically and concrete and timber do to a large extent. Some plastics, especially the thermosetting types, also are essentially elastic within appropriate stress limits. Deformation is proportional to the load applied and disappears quickly when the load is released.

Plastic behavior, in contrast to elastic, involves flow or creep of the materials under load, so deformation depends not only on the load, but also on the rate at which it is applied and on its duration. When the load is removed the material may eventually recover all or part of the deformation. Especially under high stress, it is likely to increase with time. The same is true of metals at high stresses and at elevated temperatures.

Many plastics, especially the thermoplastics, exhibit time-dependent plastic behavior. The effect is greater at elevated temperatures and may be quite marked at temperatures found in buildings, such as hot-water lines, and roofs and walls exposed to the sun. These materials become stiffer and stronger as the temperature drops. Eventually most of them become brittle, some at temperatures in the vicinity of 0° F, others at much lower temperatures. Their strength, and the amount of deformation before failure occurs, also depend on the rate at which they are loaded. If loaded quickly they carry higher loads, but stretch or otherwise deform less before failure, than when loaded slowly. The effects of temperature and rate on the load-deformation behavior of such materials are shown in the stress-strain curves of Figure 1.14.

Materials which exhibit plastic behavior are subject to creep. When loads are imposed these materials tend to continue to deform as time passes. The degree of creep depends on the range of stresses and temperatures encountered. If stresses are low enough and temperatures are moderate, creep is small and may be of no particular importance. This is brought out in the lowest curve of Figure 1.15 which shows a typical low-stress creep curve at moderate temperatures in which creep eventually dies off to zero. This curve shows also that if the load is removed the material eventually returns to its original undeformed condition. The second curve shows a condition of higher stress in which creep continues to increase slowly with time. If continued long enough this may lead to failure. If unloaded, most of the deformation is recovered, but some residual deformation remains. As stresses or temperatures increase, creep also increases and may lead to rapid distortion and failure, as shown in the upper curve of Figure 1.15. Plastic pipe, for example, which might be entirely satisfactory for cold water at normal pressures could well be completely unsatisfactory as a hot-water line.

Engineers, builders, and architects are familiar with the fact that the strengths of materials are dependent upon temperatures, stress, and duration of load. For many construction materials these factors are of relatively minor significance, however. In the case of many plastics, particularly thermoplastics, these relationships are of major significance and must be taken into account, otherwise, failures may occur. Appropriate stress levels and factors of safety must be employed, therefore. For materials exhibiting no sharply defined yield points or elastic limits, the working stresses are more dependent upon the degree of creep which can be tolerated.

Fillers and Plasticizers: Plastics are modified greatly in their properties by the judicious addition of fillers and plasticizers. Fillers are used primarily with thermosetting materials and plasticizers primarily with certain thermoplastics. For example, a pure thermosetting material like phenolic resin is hard to mold, is fairly costly, and is quite brittle. If wood flour is added, it is much more moldable, it is cheaper, it shrinks less in the mold, and it gives a better product. So for general-purpose moldings, material like phenolics are loaded with wood flour. On the other hand, if high electrical properties are required, it is customary to add mica. For high heat resistance asbestos fiber is added. Chopped fabric or chopped tire cord markedly increases the toughness and the strength. White, pure, alpha cellulose is added to the light-colored thermosets, such as dishes made of molded melamine. Clay and other inorganic fillers may be added to reduce cost, increase temperature and flame resistance, and to provide better stability and lessened shrinkage. The same basic resin, therefore, may be given a wide range of properties depending upon the type of filler that is added. In Figure 1 the ranges of strength properties shown for the phenolics, urea, and melamine resins are the result of adding different fillers in varying quantities.

Plasticizers are commonly used with certain thermoplastics, which are too brittle and too hard to be molded at temperatures below their decomposition temperatures. Others, although moldable, may be too hard and brittle for their intended uses. Plasticizers make them more flexible at ordinary temperatures. They have much the same effect at ordinary temperatures as heat has in increasing plasticity, flexibility, and, frequently, toughness. Strength is generally decreased at the same time. So by varying the plasticizer content, the same plastic can be varied from hard, rigid, and brittle to soft, distensible, and tough. The cellulosics and polyvinyl chloride are particularly good examples of the use of plasticizers to provide a wide range of hardness, strength, and flexibility.

Orientation: When certain plastics are drawn into fine filaments, their strength rises considerably. This property is utilized in the manufacture of textile materials. Although textiles are beyond the scope of this conference, it is interesting to see in Figure 1 how the vinyls and nylon, for example, are increased in tensile strength when drawn into filaments. Many of the other high-strength textile materials are obtained in a similar manner.

Copolymers: Several basic plastic types may be built into the same molecular chain. A wide range of properties may be obtained, depending on the types and proportions of basic plastics employed. Many such combinations, called "copolymers," exist. The range of properties for styrene and the acrylics stems largely from copolymerization. The cellulosics and vinyls similarly can be copolymerized in addition to being plasticized.

Stiffness: Compared with traditional structural materials, the stiffness of plastics as measured by modulus of elasticity is generally low. As shown in Figure 1.16, the thermosetting materials, such as phenolics, urea, and melamine, are in the same general range as wood and concrete. The rest of the plastics, other than the laminates and reinforced plastics, rank lower than all the traditional structural materials. All of the plastics rank well below all of the metallic alloys. Magnesium, not shown because it is not customarily found in buildings, ranks slightly higher than the upper limits of the plastics.

The modulus of elasticity of plastics requires some explanation. For most construction materials, the modulus of elasticity is defined as the ratio of stress to strain at some specified portion or point of the stress-to-strain curve, as determined by a standard test. Variations from this value are not great under ordinary conditions. The same holds true of those plastics which exhibit little or no creep. If creep occurs, however, strain is no longer directly proportional to stress; the plastics part sags or otherwise distorts under load with time. The stiffness, or modulus of elasticity, in effect decreases. The modulus of elasticity, therefore, varies with time and per-

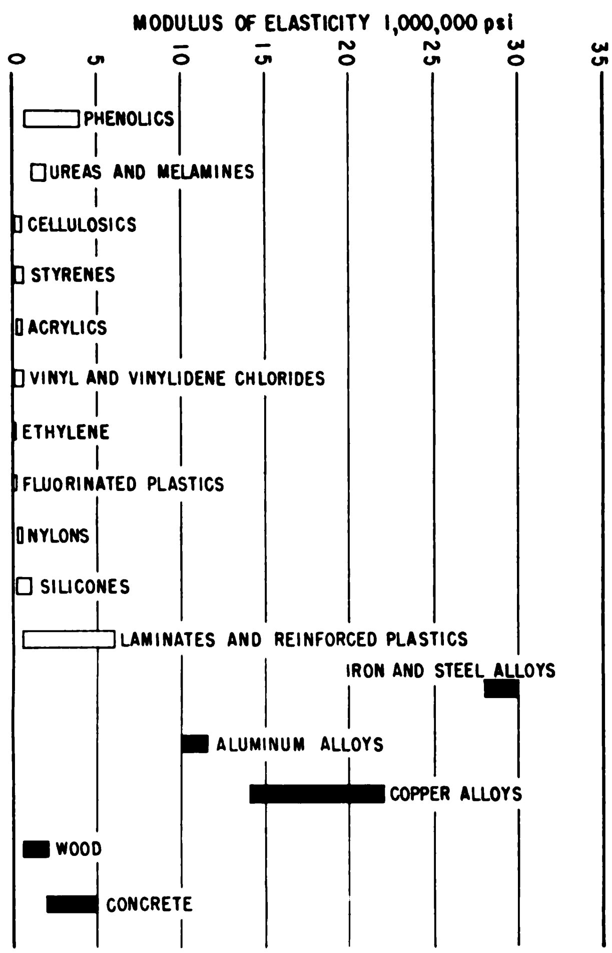

FIG. 1.16: Modulus of Elasticity of Plastics and Various Other Materials

haps ought to be called modulus of plasticity. By taking this into account and by using correspondingly reduced moduli, plastics parts can be designed for long-time loading and long-time allowable deflections.

LAMINATES AND REINFORCED PLASTICS

Where large size or high strength are required, the answer is usually found in laminates and reinforced plastics. These are materials in which plastics have been combined with sheet or fibrous materials to produce a composite which has properties unavailable in either constituent alone.

The term "laminate" usually refers to a sheet material which has been made under high pressure and high temperature. The term "high-pressure laminate" is often used to differentiate this class of materials from reinforced plastics, which were formerly called "low-pressure laminates."

Paper, fabric, wood, and other sheet materials are combined with thermosetting resins, usually phenolic or melamine or both. The usual procedure is to impregnate the sheet stock, dry, assemble the dried sheets, and press under temperatures ranging up to 350° F and pressures ranging from 1,000 to 3,000 pounds per square inch. The building industry uses large quantities of these materials for table tops, counter fronts, furniture, wall covering, and other applications where their strength, toughness, resistance to marring, and resistance to water, alcohol, and other commonly found solvents, make them particularly useful because maintenance costs are low and refinishing costs are largely eliminated.

Reinforced plastics refer to plastics employing fibrous reinforcing agents. These plastics almost always contain some form of glass fiber combined with a liquid resin which is converted to a solid by catalysts and hardeners, with or without heat or a moderate degree of pressure. Because the heat and pressure requirements are moderate, it is possible to make large, compound-curved parts in relatively simple molds. This is in contrast to the tool steel molds and heavy presses required for ordinary molding and for high-pressure laminates.

Familiar examples of reinforced plastics are auto bodies, boat hulls, the corrugated sheet beginning to be used in large quantities in buildings, and a large variety of similar applications. The fibers in reinforced plastics are mats or woven fabrics. Many types of weave, including plain cross weave, satin or crow's-foot weaves, and unidirectional weaves, in which practically all of the filaments are aligned in one direction, are employed in reinforced plastics. The same fabrics, of course, are used with high-pressure laminates.

The engineering design of laminates and reinforced plastics introduces some interesting and complex problems which are faintly similar to the problems of reinforced concrete design. In the design of structures made of metal or plain concrete, it is assumed that the materials are homogeneous and have the same properties in all directions, i.e., they are "isotropic." When plastics are combined with fabrics, especially unidirectional fabrics, the strength properties are strongly influenced by the directional properties of the fabrics. Such familiar constants as modulus of elasticity and Poisson's ratio become variables, depending on direction. Strength, of course, is also greatly influenced by direction. The same plate may easily vary ten to twenty-fold in these properties, depending on the weave of the fabric. Surprising and complex interrelationships of stress occur within and between the layers of the laminate. The engineering designer must be wary and alert, therefore. Figure 1.17 shows how some of these properties may vary with respect to the direction of weave.

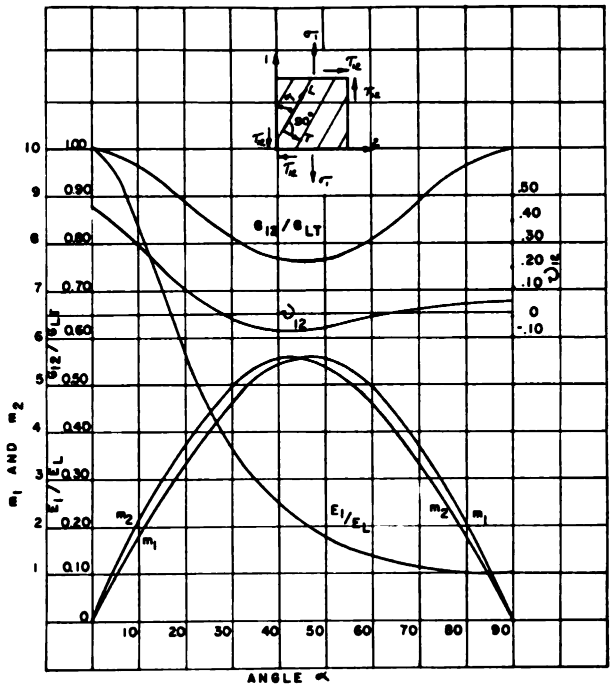

FIG. 1.17: Effect of direction of weave upon elastic constants of reinforced plastics and laminates

The extremes of strength properties shown in figures 1.13 and 1.16 are reflections of these directional effects. At the low end, the properties are largely those of the resin alone. At the high end are found rods containing a very high proportion of glass filaments which are all carefully aligned in one direction.

The variety of reinforcing materials available, and the freedom with which they may be arranged to meet the loads imposed, gives the engineering designer wide latitude in tailoring materials to meet his requirements. Furthermore, engineering and architectural designers have practically unlimited freedom in selecting shapes and forms to enclose spaces and in choosing their structural elements in the most advantageous manner.

SANDWICH CONSTRUCTIONS

In sandwich constructions, two thin, hard, strong facings are combined with a relatively thick, lightweight, weak core to provide a combination of lightness, strength, and rigidity. The facings provide the strong elements but because of their thinness would buckle under bending and compressive stresses. They must be supported laterally by the core which is stiff enough to provide this support. The core must also resist the shear stresses occurring in the sandwich as it bends. The adhesive bond between facings and core must resist shear and tensile stresses between these components.

Many combinations of materials can be employed in sandwiches. The building industry already uses sandwiches composed of insulating board cores and cement-asbestos facings, lightweight concrete cores with metal facings, and various others. Plastics enter into this picture by providing structural and decorative facings of high-pressure laminates or of reinforced plastics. Cores are made of foamed plastics or of honeycombs of resin-impregnated paper. The high-strength engineering adhesives based on plastics bond all sorts of facings and cores together.

THERMAL CONSIDERATIONS

Thermal Expansion: In building design it is frequently necessary to take into account the thermal expansion and contraction of materials. This is particularly true of such items as metal roofs, gutters, and pipe lines. The large metal window frames in glass-faced buildings also present a particular problem. Among traditional materials, aluminum and copper and their alloys have higher coefficients of expansion than the iron-based alloys. Wood has a low coefficient parallel to the grain but a quite high coefficient perpendicular to the grain, especially in dense woods like yellow pine and birch. Swelling and shrinking because of moisture changes usually "mask out" thermal expansion perpendicular to the grain. Concrete also changes because of both thermal and hygroscopic effects.

It may come as a surprise to some that thermal coefficients of expansion of plastics are high, as shown in Figure 1.18. There is a widespread notion that plastics are stable materials thermally, when actually they expand and contract considerably more than metals. In the design of plastics parts, especially if they are to be used in conjunction with other materials, this feature must be kept in mind. It is not insurmountable, but it is something to allow for in design.

Thermal Conductivity: Like most other nonmetallic materials, the thermal conductivity of plastics is low, although it varies from plastic to plastic. In Figure 1.19, plastics are compared with wood and concrete at the left-hand side of the figure and compared with iron, copper, and aluminum alloys at the right. Few of the plastics approach the heat insulating value of wood perpendicular to the grain, the lowest value of wood, but all are vastly better insulators than any of the metals.

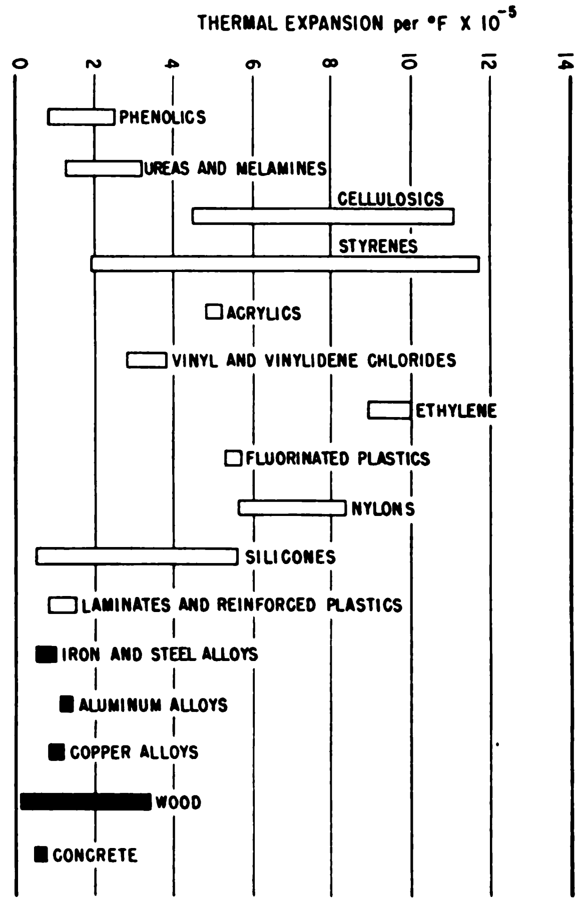

FIG. 1.18: Thermal Expansion of Plastics and Various Other Materials

DURABILITY

Corrosion: Resistance to corrosion and to attack by a wide variety of solvents is among the most attractive features of many plastics. At least one plastic material can be found to resist practically all corrosive conditions encountered in building. The fluorinated plastics are particularly outstanding and are used in the highly corrosive applications in the chemical industry. Polyethylene is highly resistant to attack by a wide variety of corrosive materials at temperatures below its softening point. The silicones are inert and, like the fluorinated plastics, highly moisture repellent. Moisture absorption by other plastics varies from practically zero to moderate. Some plastics are selectively attacked by classes of solvents, so that the choice for any given condition should take this selectivity into account. For corrosive conditions normally encountered in buildings, the plastics as a whole are excellent.

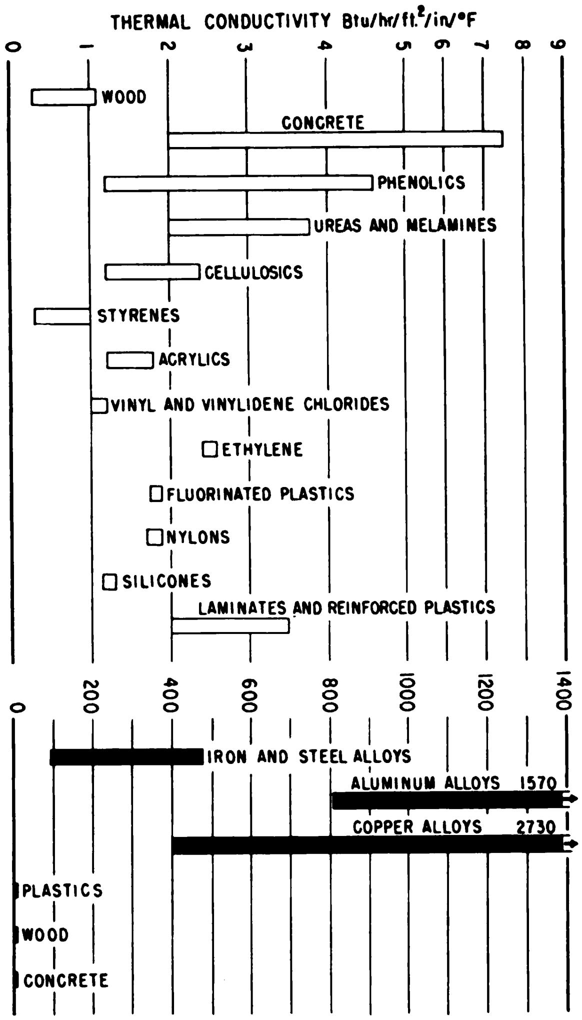

FIG. 1.19: Thermal Conductivity of Plastics and Various other Materials

Heat: All plastics can be destroyed by fire. They may burn easily or they may be self-extinguishing, depending on the basic resin and the fillers and plasticizers used in compounding them.

Building designers recognize that resistance to fire is a matter of proper design to a large extent as well as the proper selection of materials. Buildings constructed of incombustible materials have had disastrous losses in fires, whereas other buildings of combustible materials have stood up well. Nevertheless, it must be kept in mind that all plastics can be destroyed by fire and that many of them burn easily of their own accord once they are ignited.

Maximum temperatures to which plastics should be exposed have not been easy to establish because use conditions are extremely variable. Maximum recommended temperatures for more or less continuous exposure are given in Figure 1.20. The temperatures given for metals and concrete are the temperatures at which strength drops approximately 50

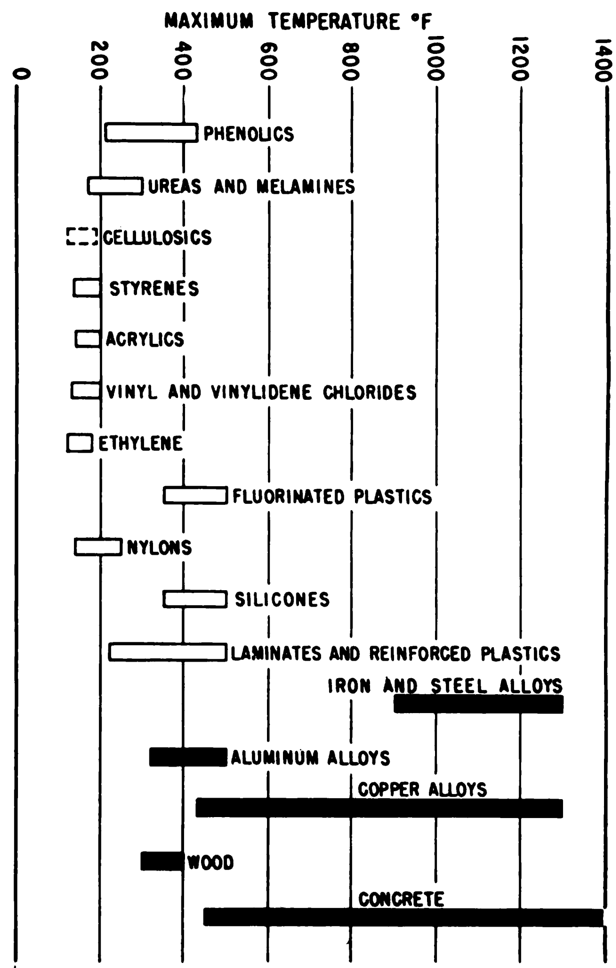

FIG. 1.20: Approximate Temperature Limits for Plastics Compared with Various Other Materials

per cent. The wood temperatures are based more on charring than on loss of strength because wood does not become weaker upon heating. Concrete temperatures are uncertain because when concrete is used as fireproofing for steel, its insulating value rather than its strength is important. On the other hand, some lightweight concrete load-bearing structures easily may lose more than half their strength at fairly low temperatures.

Among the plastics the silicones and the fluorinated plastics have outstanding temperature resistance. Laminates may be highly resistant if the basic plastic resin is resistent and the reinforcing agent is an inorganic material like glass or asbestos. Other plastics, especially the thermoplastics, are sensitive to heat, so the recommended temperatures are based upon creep and distortion rather than ignition temperatures. Manufacturers of the cellulosics, because of the range of basic types and of plasticizer contents, hesitate to recommend specific maximum temperatures. Thermosetting plastics, as is to be expected, are generally superior in heat resistance than the thermoplastics.

Irradiation of some plastics has been shown to raise their heat distortion temperature markedly. Polyethylene bottles, for example, which collapse or distort badly at 150-175°F retain their shape at temperatures between 300 to 400°F after irradiation. A cross-linking action occurs binding the molecules together in a structure similar to thermosetting plastics and thereby raising their resistance to distortion by heat.

Weathering: Resistance to weathering over a long period of time is one of the most uncertain factors of plastics. There is reasonably good certainty that indoor exposures should have relatively little effect on most plastics, although outdoor conditions may affect many of them adversely. Many of the large-volume plastics in use today were emerging from the laboratory 10 to 20 years ago and changes in formulations are being made continually. For many plastics, therefore, there is no record of outdoor exposure extending over long periods.

Transparent plastics, of which the acrylics are the best example, have been used for aircraft glazing and other outdoor applications for periods ranging up to 20 years. Their performance is, therefore, relatively well known and they can be expected to give a good account of themselves in buildings. The phenolics also have had a fairly long history of outdoor exposure. Loss of gloss and dulling of colors can be expected to occur upon weathering, but properly formulated phenolics otherwise have given a good account of themselves outdoors for periods of 20 years or more.

Long histories are lacking for most other plastics, but the chemical nature of the fluorinated plastics and the silicones indicates that they should have outstanding long-time weather resistance. High cost stands in the way of large-scale use of these materials, however. Certain of the vinyl and vinylidene compounds, especially when formulated with carbon black and other ultraviolet light-excluding pigments, show promise on the basis of exposure histories ranging up to ten years.

The lack of completely reliable accelerated weathering tests, which are difficult to set up because of the complexities and vagaries of actual weather, is a serious obstacle to the adoption of promising new plastics as they appear. In building, the customary units of time are 20 to 50 years, although it may be argued that practically all buildings are absolete before that time. Building designers hesitate to use materials which have not proven themselves in actual use. This attitude, while perhaps a deterrent to rapid progress, is understandable and plastics manufacturers must recognize that it exists.

BUILDING TRENDS

Several major trends in building design and construction are bound to have a decided influence upon the potential uses of plastics in building.

FIG. 1.21: Aluminum Exterior Wall Panel

Perhaps the most important is the trend toward shop-fabricated units which are assembled quickly in the field to reduce expensive field time and field labor. Large shop-fabricated building panels—particularly for walls, but also for floors and roofs—are becoming common not only in dwelling houses but also in industrial and commercial buildings.

The "stressed-skin" principle is already in use, especially in housing. The application of load-carrying sandwiches also is beginning to grow in this field after the pioneering efforts of the aircraft engineers. A major problem, still calling for a completely satisfactory solution, is the caulking and sealing of joints between these panels. The highly durable, though expensive, plastics might help to solve this problem.

Built-in features of all kinds are being shop-fabricated to a greater and greater extent to reduce field labor and erection time. Portability, including minimum weight and resistance to damage in transit, becomes important. Plastics' lightness and flexibility of design, coupled with good strength and impact resistance, can make them attractive for all of these applications.

Figure 1.21 shows an aluminum exterior wall panel being put into position on a multi-story office building. In this particular instance, the panel was backed with cast-in-place, light insulating material and then was plastered on the inside. A sandwich with built-in insulation, finished on the inside with a material like decorative laminate, should be feasible here. The

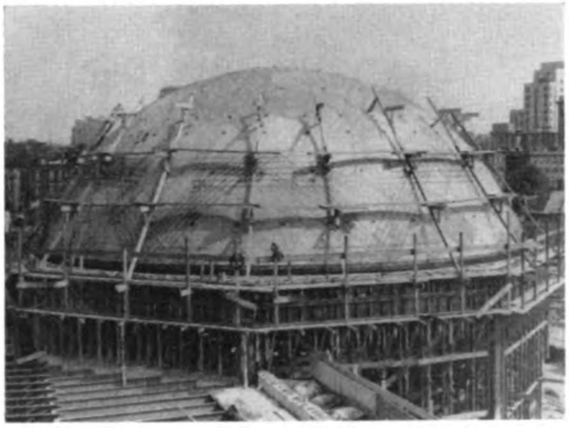

FIG. 1.22: Thin Shell Concrete Dome

sealing of the joint becomes a major item, as indicated previously.

A second major trend is toward large clear spans which avoid internal supports. This provides freedom for industrial operations and allows for easy rearrangement of office space. Even in dwellings there is a trend toward roof constrction spanning from outside wall to outside wall to eliminate bearing partitions and to allow for free arrangement of space. Consequently, flat slabs, cantilever construction, and long spans are becoming common in buildings. There is also a trend toward the highly efficient structural shapes such as shells, domes, arches and vaults for the spanning of exceptionally large spaces. Space frames also are efficient for the enclosing of large spaces.

It is entirely possible for plastics, although they may not be used for the primary load-bearing members such as arches, to be fitted into the structure in the form of secondary load and light-transmitting units. The readiness with which many plastics can be formed into complex shapes recommends them for these purposes over other materials not formed so readily.

The ready formability of materials like reinforced plastics recommends them for the making of complex grid and cell forms for reinforced concrete construction. Such forms have already been used for precast concrete slabs, and this use could be extended easily, particularly where complex shapes are required and where the forms are reused many times. A major problem exists, for example, in the forming of large-span, thin concrete domes. A strong deterrent to the greater use of these efficient structural shapes is the cost of forming. It is conceivable that segmented forms could be built which would rotate about a central axis as the dome is cast, thereby reducing the amount of forming material required. Possibly plastics could provide the tough curved surfaces of such forms.

Figure 1.22 brings out difficulties in forming thin-shell concrete domes. The falsework ribbing and

FIG. 1.23: Ribbed Floor Concrete Construction

sheathing required for the forms of a dome such as this can easily constitute half the total cost of the dome. All of this must be erected and then taken down, much of it as scrap.

Figures 1.23 and 1.24 illustrate some of the possibilities in reinforced concrete grid construction. These Italian examples by Pier Luidi Nervi show imaginative engineering in the arrangement of ribs and cells for the most efficient handling of stresses in slabs and vaulted roofs. The cost of forming by usual methods would be considered prohibitive in the United States. Here, again, reinforced plastics

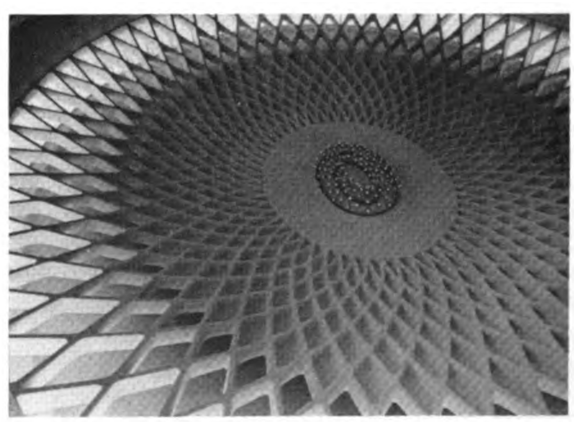

FIG. 1.24: Ribbed Concrete Domed Ceiling

FIG. 1.25: Glass and Metal Exterior Skin

FIG. 1.26: Reinforced plastic radar enclosure

or similar materials might be useful, provided there were enough reuses of the forms. Experience has shown that such forms can be reused a large number of times.

A third major trend, coupled with open plans and minimum interior obstructions, is the greatly increased use of transparent and translucent walls. These walls admit maximum sunlight and provide a feeling of spaciousness. Transparent and translucent panels, particularly if they combine light transmission and structural qualities, are highly desirable for such buildings.

Sandwich panels having a combination of structural attributes and light transmission are being developed for these purposes. Such panels carry at least part of the superimposed floor and roof loads and are sufficiently strong to withstand wind pressures. In this connection the ready formability of plastics allows for the development of structurally efficient shapes providing light-transmittance. At the same time, plastic panels are able to provide the necessary shading to prevent undue overheating of interiors by bright sunlight. The solar load can become a major problem in buildings with light-transmitting walls. Outward heat loss is another problem for which double-walled units could help to provide a solution.

Figure 1.25 shows a recently-built glass-walled building, which is typical of the trend toward open walls. Heat-absorbing glass, blinds, and various other devices are used to lessen the solar heat load when walls are exposed to the direct sun. Nevertheless, the load imposed can become severe. The readiness with which transparent and translucent plastics can be formed suggests that by properly shaping the units in an exterior wall much of the load could be reduced by high-angle reflection and shading.

A fourth major trend is the increasing importance of mechanical and electrical equipment for air conditioning, illumination, power, and multiplicity of services required in a modern building. This is coupled with the necessity for flexibility to match the flexible planning associated with large open areas. When space is rearranged, the mechanical and electrical services also must be rearranged. Flexible piping, conduit, cable, and ducts are required. Continuous electrical outlets are desirable. Luminous ceilings are often called for.

The open planning and lightness of construction involved pose problems of thermal insulation and particularly of acoustical control, which must often be combined with over-all illumination in ceilings. Plastics can make a decided contribution to all of these problems if they are used with imagination and understanding of their possibilities and limitations.

Radar Enclosure: A large radar enclosure recently built of reinforced plastic (Figure 1.26) illustrates an application in which the formability and properties of this material were used to meet the requirements of the problem. The rotating motion and the general shape of the radar equipment made a dome-shaped enclosure the logical choice. This shape is efficient structurally and aerodynamically, considering the fact that it must withstand winds from any direction. Its exposed position atop a building in a large open area makes wind loading the most important structural consideration. Electrical requirements ruled out any metal in the enclosure.

From an analysis of wind loading based on the best available wind-tunnel data, it became apparent that reinforced plastics could easily withstand the imposed stresses. The surface was divided into triangular segments to approximate the shape of a sphere. Molded reinforced plastic units, each incorporating several triangular segments, were fabricated. At the edges of the units downstanding stiffening lips were formed and reinforcing ribs were formed along the lines of the basic triangles. Glass fiber mat was employed for the surfaces, and additional strength was achieved at the lips and ridges with woven glass fabric strips molded into these thickened sections.

As the illustrations show, the units were field assembled without great difficulty. A high degree of transluscence is achieved together with structural strength. Here, therefore, is a combination of enclosure, structure, and light transmission in which plastics played the essential role. Incidentally, the dome withstood the August 31, 1954 hurricane without damage.

SUMMARY

This discussion has attempted to set forth the ranges of strength, stiffness, thermal properties, corrosion resistance, and durability of plastics in comparison with familiar metals, wood, and concrete used in building. It has touched briefly upon the engineering aspects of laminates, reinforced plastics, and sandwiches. It also has attempted to show the major trends accurring in building design and to indicate how plastics fit into these trends. Many of these items, briefly mentioned, will be amplified in other discussions.

One conclusion should be clear. Plastics possess their own combination of advantages and limitations which set them off from other materials. Attempts to use them like other materials are likely to produce unhappy results. Properly and imaginatively used, with an intelligent understanding of their properties, plastics can contribute significantly to the advance of building technology and design.

EVALUATING PLASTICS FOR BUILDING APPLICATIONS

By Tyler S. Rogers*

Owens-Corning Fiberglas Corporation

THE use of plastics in building, as in any other field, is stimulated by certain of their properties and limited by others. Which properties are desirable and which are limiting varies with the use for which the product is intended. This evaluation of plastics for building applications is an attempt to appraise the relative significance of the broadly positive or negative factors without getting into the detail that will necessarily fall within the scope of other speakers dealing with specific forms and applications of plastics.

Professor Albert G. H. Dietz has summarized the physical and engineering properties of plastics and has interpreted them in relation to current building trends. Dr. E. B. Cooper has told us about the resins used to form plastics. Two other factors must be taken into account before we can properly evaluate plastics for building uses.

One of these is the molding and fabrication of plastics, because the processes employed have a bearing on sizes, properties, and costs. The other is the economic relationships of plastics to similar products made of other materials. These two factors are quite closely related.

MOLDING METHODS

An experienced plastics fabricator recently said: "It is easy to make plastic products but very difficult to make good ones."

The final product is influenced by all manner of variables, including the fillers used, the temperatures and pressures employed in molding operations, workmanship, and even the prevailing humidity. Skill and experience enable good fabricators to produce good plastic parts. The industry has suffered, however, from the inferior products which result from poor fabrication.

Molding methods influence the use of plastics in buildings because they affect properties, sizes, and costs. The various types are more easily illustrated than described, hence the accompanying figures will indicate the various methods available to the fabricator.

Representative methods of forming plastic parts are shown in the accompanying diagrams (Figures 1.27 to 1.40) taken from the book, "Fiberglas Reinforced Plastics," by Ralph H. Sonneborn.

The choice of fabricating method obviously is governed by the size and complexity of the part, the number of parts required, the quality of surface finish and the type of resin employed.

RELATIVE COSTS

Costs are extremely important in any discussion of plastics in building. In some types of product, the use of plastics has become widespread for the simple reason that no other material or fabricating method will produce the unit at such low cost. In many other cases, especially in the realm of reinforced plastics, the economic advantage, if any, depends on a number of related factors.

Generally, molding resins cost from 10 cents to 50 cents per pound, with some special resins costing even more. Steel may cost from 6 to 10 cents per pound, with special grades in higher brackets. If steel can be formed by stamping, the cost is concentrated on the forming dies and huge presses. Once

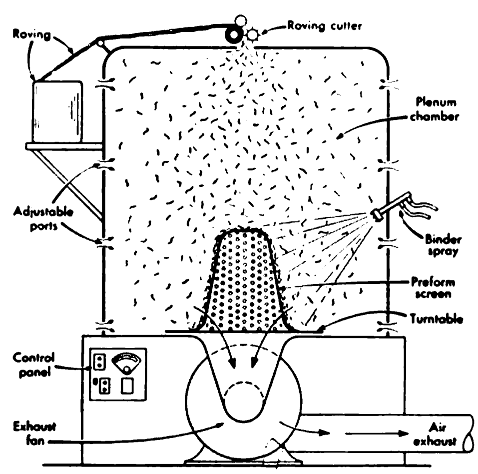

FIG. 1.27: Plenum chamber preform process

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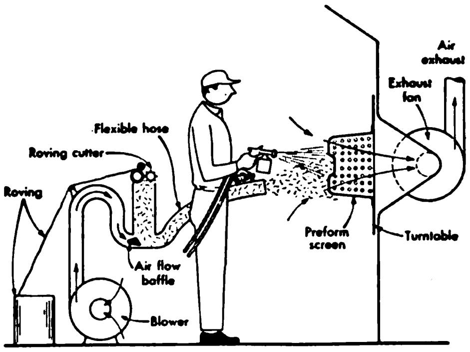

FIG. 1.28: Directed Fiber preform process

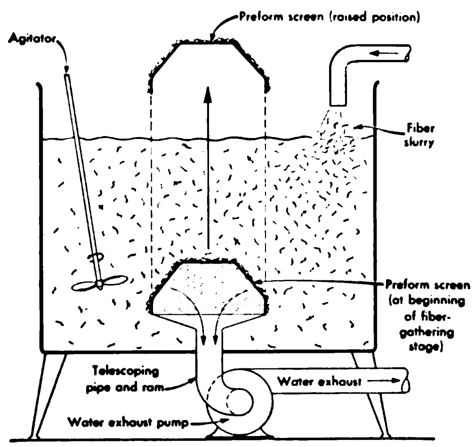

FIG. 1.29: Water slurry preform process

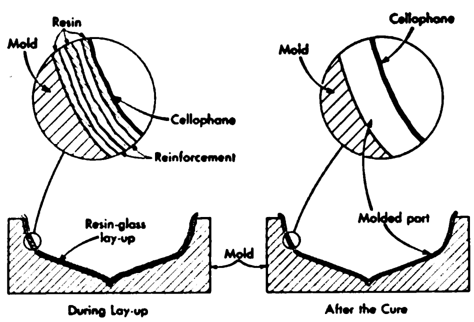

FIG. 1.30: Contact molding process

these are available, the parts can be stamped out very rapidly.

A plastic part also requires dies or molds of some sort, as we have seen. It may require a press or it may not, depending upon forming method and resin. But all resins require some time to cure, ranging from slightly less than a minute up to several hours. This time factor adds to costs because it ties up equipment as well as manpower and limits the rate of output of the facilities.

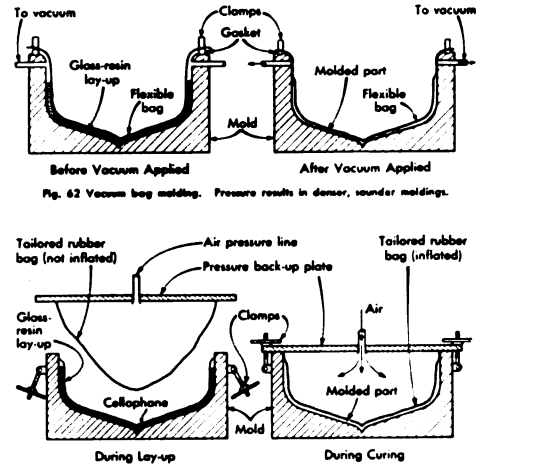

FIG. 1.31: Bag molding. Vacuum (top) and pressure

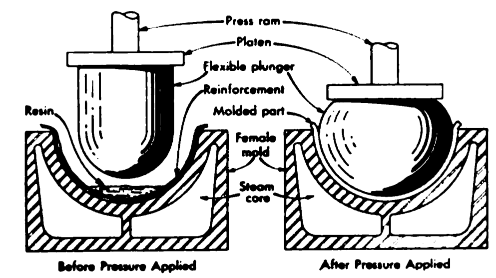

FIG. 1.32: Flexible plunger molding process.

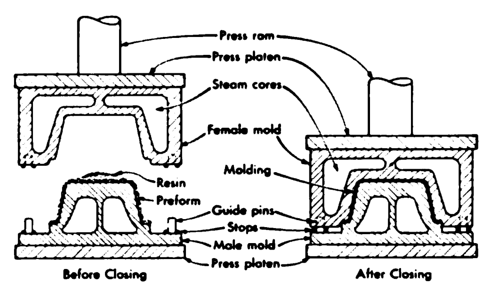

FIG. 1.33: Matched die molding process.

These relations are shown by Sonneborn[1] in Figure 1.40 comparing two plastics molding processes with steel stamping. For a very few parts—perhaps from one to 10 or 20—vacuum bag molding is least expensive. For a larger number of complex parts (up to about 15,000 in the example chosen) matched die molding will produce parts at less cost than steel stamping. But note that the cost curves for plastics do not drop down appreciably as the quantity of parts increases, whereas with steel stampings the curve continues to drop until a very low unit cost is reached.

[1] Fiberglass Reinforced Plastics Ralph H. Sonneborn, Reinhold Publishing Corporation, 1954.

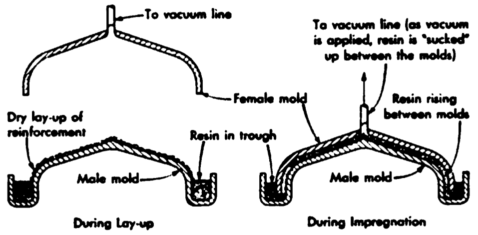

FIG. 1.34: Vacuum injection molding process.

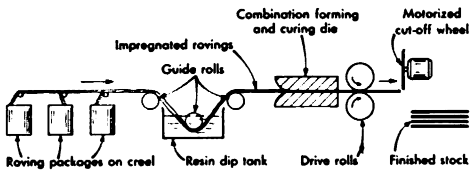

FIG. 1.35: Extrusion or die drawing process.

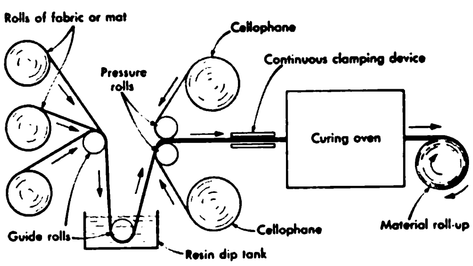

FIG. 1.36: Continuous laminating process.

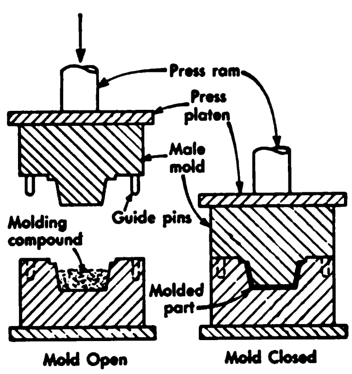

FIG. 1.37: Compression molding process.

This means that building applications calling for large quantities of indentical parts will not be made of plastics instead of metals, unless other considerations than speed and ease of forming give the plastics part an advantage. In the case of glass-reinforced plastics, the final price per pound for most products is close to $1, whereas the price per pound of finished steel products may not exceed 25 cents. Therefore we should not look for nails, screws, brackets, builders hardware and similar items used by the millions to be made of plastics, even if the necessary physical properties were present.

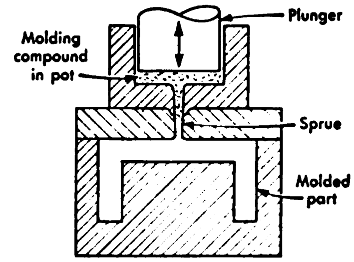

FIG. 1.38: Transfer molding process.

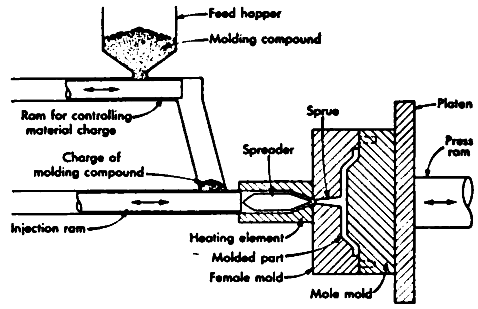

FIG. 1.39: Injection molding process

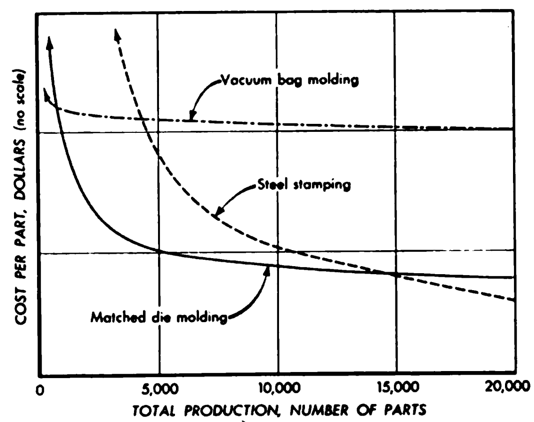

FIG. 1.40: How costs are affected by production method and quantity produced.

EVALUATION

Now looking back over the subject, considering the chemistry of the resins, the physical and engineering properties of plastics, the molding and fabrication methods, and economic or cost factors we can see where plastics appear to fit into buildings.

Among the factors favoring such uses are undoubtly these:

Formability—The ability to produce complex shapes.

Colorability—The ability to offer integrally molded, substantially permanent colors.

Durability—The comparatively stable and permanent character of plastics.

Chemical Resistance—The ability to select resins that are immune to attack by most chemicals.

Low Thermal Transmittance—A very significant factor which should be emphasized. Professor Dietz showed that where wood has a heat transmittance of 1, masonry 10 to 12, steel 310, and aluminum over 1475, the range of non-reinforced plastics is from 1 to 5 and of glass-reinforced plastics, about 1 to 2.5. This very favorable resistance to the transmission of heat is unique among high-strength materials. It suggests that plastics can be used to advantage in low temperature structures, such as walk-in coolers or commercial freezers, where nonconductive structural supports and strong insulating doors are required.

Electrical Characteristics—Leading to many applications in wire, cable, motors, and other electrical apparatus.

Clarity—The property of controllable light transmission, from transparency through translucency to opacity.

Physical Strength—The ability, through the use of glass fiber reinforcement to develop products of higher strength-weight ratio than is attained by any other combination of materials.

Among the properties that are limiting, Professor Dietz noted these:

Elastic Behavior, or Creep—Requiring consideration in design of products used under stress.

Stiffness—Generally low compared to traditional structural materials.

Thermal Expansion—Comparatively high, and usually in excess of metals. Must be considered in design.

Heat Tolerance—Since all plastics can be destroyed by fire their use, like that of wood and thin metals, must be carefully considered where failure due to fire can be hazardous.

Weathering—Mostly due to lack of data and reliable knowledge of behavior of different plastics.

Molding methods are limiting as to size and cost where large elements are required in reinforced plastics. The manufacture of small non-reinforced plastic parts may be less costly than with any other material when complex shapes, color, electrical or chemical resistance, or other properties are involved.

In summary, it appears obvious that plastics have many practical and economic uses in buildings where their unusual combination of properties fits specific job requirements. It is equally clear that each resin, each type of plastic part, and each method of fabrication imposes certain limitations that must be understood by the designer and specifier if he expects to take full advantage of their properties without paying a premium for novelty instead of utility.

GENERAL DISCUSSION

MR. HUNTZICKER: Each of the three gentlemen who have addressed you will return to the platform for the panel discussion. The moderator will be Mr. Charles J. Romieux, sales manager of the plastics and resins division of the American Cyanamid Company, New York. He is a native of Minnesota and was graduated from Harvard University in 1920. He has been associated with the plastics industry in many capacities since and he is eminently qualified to moderate this panel discussion. Mr. Romieux.

MR. ROMIEUX: In addressing your questions kindly rise, state your name, affiliation, and the speaker to whom you are addressing your question. Also bear in mind that the questions should be pertinent to the three papers that have just been delivered. The meeting is now open for discussion. May I have some questions from the floor?

MR. H. A. COOK (Dow Chemical Company): I would like to ask Mr. Rogers whether his slurry preforming is a licensed procedure?

MR. ROGERS: I cannot answer that precisely, but I think it is. I am not sure.

MR. PHILLIP H. DEWEY (Interchemical Corporation): To Dr. Dietz. Do you have any figures, or do you know where there are any figures, on fatigue of plastic materials? I understand polyesters particularly are subject to fatigue.

DR. DIETZ: I do not have such figures from our laboratory, since we have not gone into fatigue work. Some fatigue values have been published from time to time in publications of the American Society for Testing Materials and especially of the American Society of Mechanical Engineers. I would suggest that you refer to the publications of ASME and of the ASTM and other publications on the subject of modern plastics as the best place to go for information of this type. I think you will just have to go through the literature and find it. I do not know of any place where this has all been compiled. I think you will find it is incomplete.

MR. JOHN S. PARKINSON (Johns-Manville): I would like to ask Mr. Rogers whether he has any information on the behavior of plastics to outdoor exposure. I believe he mentioned there was some, although not very much.

MR. ROGERS: Mr. Moderator, I have a feeling that this subject will be developed as we have other discussions and other speeches during the two-day session. We have a panel or discussion on corrugated plastics that are used for roofs, porches, awnings and things like that, and I assume the speakers will be more specific.

MR. ROMIEUX: That question probably will be answered during the subsequent sessions. On the other hand, Mr. Cooper, you said you would touch on the matter very briefly for building applications. Perhaps you would say a few words on the subject.

MR. COOPER: There certainly is a great range in the ability of various plastics to endure outdoor exposure. This is a subject on which I would be glad to talk for an extended period, but I think it would be better to let the subject develop through the conference, as Mr. Rogers suggests.

MR. ROMIEUX: May I add a comment? In plastics we are dealing with relatively new materials. We are comparing them with construction materials that have been used since prehistoric times and with which we have had experience for many, many years.

MR. GORDON BROWN (Bakelite Company): I would like to ask Professor Dietz what is the highest temperature resistance obtained so far by irradiation of polyethylene.

DR. DIETZ: I will tell you what I know about this subject and then I will refer it to Dr. Cooper. I understand polyethylene has been raised in heat distortion plants from 150°F to about 350°F by irradiation. Dr. Cooper, what do you think?

DR. COOPER: Well, the effects of the irradiation in polyethylene are to create free radicals which cause cross-linkings. This brings about an increase in stiffness and adds somewhat to the tensile strength, but reduces elongation at the same time. So I am sure the questioner will understand that when one asks: "What is the highest temperature which can be achieved?" the question would need to be qualified with reference to a particular application. One can carry cross-linking in polyethylene to a point where the plastic is completely insoluble and infusible, but these physical properties may be made completely useless. I think the field is new enough so that the answers to this question would need to be dealt with in connection with a particular application. I am fearful that a general answer cannot be made; at least, I cannot make it.

MR. ROMIEUX: Thank you, Dr. Cooper. Any further questions?

MR. J. M. BALL (Midwest Rubber Reclaiming Company): Dr. Cooper, what is the commercial significance of the crystalline structure of polyethylene, nylon, and other plastics?

DR. COOPER: The crystalline structure in thermoplastics meets the requirements for stiffness and rigidity at ordinary temperatures. But since the crystallites melt at fabrication temperatures, they also have low-melt viscosity. It is possible, therefore, to extrude and mold the crystalline thermoplastics into very complex shapes, having thin walls and that sort of thing which takes advantage of the ease of flow. When the plastic is cooled and the crystallites are formed, many of the same benefits otherwise obtained by cross-linking are obtained.

DR. H. R. MOORE (U.S. Naval Air Development Center): Mr. Rogers, I would like to ask you a question. You developed a very interesting point about the exceptionally high strength-weight ratio of plastics in comparison with all the metals, showing that they are superior. It would seem to me that would be an excellent starting point for possible substitution of plastics developed by the industry. I wonder if you would make a comment on this problem?

MR. ROMIEUX: Mr. Rogers, could you give an example to the audience of the substitution of a plastic for metals where advantage was taken of a high strength-weight ratio of plastics.

MR. ROGERS: I know of none so far, mostly because the plastic parts which we have today are more expensive or have less temperature tolerance than the parts they replace. There are many possible explorations and opportunities. All of them require more judgment than I think most of us have yet acquired to balance the properties of present materials against these other properties. For example, you can attain a higher strength-weight ratio in a plastic part than in any other known material. But the cost is so high that to my knowledge, the only present application of materials with such high strength-weight ratio is in aircraft where the frame manufacturer can afford two or three dollars a pound to save a pound of weight. That situation does not yet apply to the building industry.

MR. ROMIEUX: Professor Dietz, do you want to make a comment on that question?

DR. DIETZ: I think I agree with Mr. Rogers that generally costs have been so high that there have been no direct applications in building so far. I would like to point out that in dome-shaped structures the weight of the structure itself is usually the deciding factor in engineering design. Thin-shelled concrete domes, for example, have been built several hundred feet in diameter and only several inches thick. Even in those cases the weight of the concrete was a deciding factor in the design of the dome. Generally, stresses are so low as to be almost ridiculous. There might be a place in this field where the favorable weight-strength ratio could come into the picture.

MR. ROMIEUX: Has an experimental structure of that type been built or is one being built in Canada? Does anyone have any information on one in Canada?

MR. ROGERS: I don't know of any in Canada, but the dome of the Ford Rotunda was made of a reinforced plastic in that fashion by Buckminster Fuller, who has been doing some very interesting work in this field for the Air Force and with various architectural schools in this country. I think he is doing some exploratory work with McGill in the University of Michigan in that same area, but I am not sure.

MR. GEORGE E. STREHAN (Consulting Engineer and Architect): To Professor Dietz: In view of the great flexibility, low modulus, and comparatively high deformations of plastics, would you recommend a larger ratio between working stresses and ultimate strength of plastics than is commonly used for steel and other materials?

MR. ROMIEUX: Professor Dietz, in designing with plastics, in view of their relatively low modulus and increased elastic properties, would you use a higher factor of safety than when using other materials?

DR. DIETZ: I think the factor of safety has to be determined on the basis of the particular application. At higher temperatures, for example, a material that shows greater creep should be used at lower stresses. A higher factor of safety would be involved, therefore it is hard to say what the factor of safety should be. Very frequently it would be higher in the case of plastic than it would be for other materials. On the other hand, on what basis do you specify a factor of safety? In the case of steel, we like to design on the basis of yield point. Many plastics have no definite yield point, so you have to determine what the creep tolerance is going to be. How much creep will you allow in a structure for a given length of time? If you determine that, then you determine what your working strength may be. The factor of safety for strength may be high or it may be low.

MR. STREHAN: What I had in mind, Professor Dietz, is whether the recovery of these materials after removal of stress should be given recognition in the design of a building. Particuarly, I have in mind that the working limits of these plastics is somewhere, as has been said, between 200° and 400°F. When we design buildings we are designing for operation under normal temperatures but we still provide generally that that structure shall resist temperatures of 1700° to 2000°F.

DR. DIETZ: If you want your plastics to withstand 1700° and 2000°F, better forget it. But there are plenty of applications at lower temperatures where plastics are still permissible.

MR. ROMIEUX: I think we want to bear in mind most plastics are organic material. As a general rule, organic material can resist stress in proportion to its weight.

MR. W. W. WOOD (SMALL HOMES GUIDE): When Mr. Rogers spoke of the very elemental equipment and the low cost factor, I am wondering what possibilities there might be for development in the do-it-yourself market. The "ham," for instance, helped the radio.

MR. ROMIEUX: Mr. Rogers, in view of the low cost and the simplicity of the materials involved in fabrication, what advantage is to be gotten from further promotion in the do-it-yourself field?

MR. ROGERS: I think some smart manufacturer who wants to put up resin in cans, as several have already done, for such uses as overcoating boat hulls, can get himself quite a nice do-it-yourself market. It is a lot of fun to play with, it is sticky and messes you up, you can buy a lot of extra gadgets to play with, and so everybody will be very happy.

MISS MARILYN GRAYBOFF (Architectural Forum): I have a simple question for Professor Dietz. In that chart on the thermal conducitivity of plastics were any of the foam plastics taken into account? Would that greatly alter the situation?

MR. ROMIEUX: I think we understand your question. Professor Dietz, in the tabulation of coefficient of thermal conductivity, did you take into account the foam types of plastics?

DR. DIETZ: No, these are the dense plastics. The range of the foam plastics, of course, would be only about a quarter of the figures given there. Depending upon densities, you can get values right down to those of cork and the various other insulating materials.

Part II

SPECIFIC USES OF PLASTICS IN BUILDING

LIGHT-TRANSMITTING PANELS

By John S. Berkson*

Alsynite Corporation of America

I SHOULD like to discuss specific applications of plastic materials—especially fiberglass-reinforced materials—in the light-transmitting field. Other papers will be delivered here which will cover quite well. I am sure, some of the other applications. The very materials which make these products possible are new, and so, of course, the products themselves are new.

Glass-reinforced panels are not to be inferred to be the only light-transmitting medium in the plastics field. And, that is not the only application for those materials. They have been used for many other purposes. You have probably examined the center panel (a fiberglass-reinforced panel) in the exhibits displayed at this conference. Many of you, I know, are familiar with that type of product. Its uses are varied. It has qualifications which we think are adequate to meet the requirements that are generally impossed upon it.

There have been questions raised this morning as to the weather resistance of this material. The weather resistance—I must admit—is not all that is desired. We haven't reached a point where we can sit back and say that this material will stand up forever. It won't. However, we know of no material that is entirely impervious to weathering.

These materials have been improved greatly over the last seven or eight years. When we think back to the panel that was produced seven or eight years ago, well frankly, we hang our heads a little bit. However, it isn't so bad today; it's better and getting better all the time. Research by the resin manufacturers is bringing rapid results. There are developments in techniques by processors, such as ours, which are also helping us.

I think that today you can use this kind of panel, with confidence, for many types of exterior applications. One, with which you may be familiar, is in the awning field. This particular material has been used increasingly for awnings in the last two or three years. You question, perhaps, why we should use a light-transmitting material for awnings. There are several reasons.

First, it permits you to get the advantage of an awning and at the same time avoid the darkening of the room behind it. It is material that has a very high diffusing factor, which actually raises the light factor toward the back of the room. Second, it does very definitely cut down direct rays, reduces fading problems within the room, reduces the amount of heat (as other materials would), and has many, if not all, of the advantages of opaque materials like aluminum, wood, and canvas—the conventional awning materials. Since fiberglass is, at the same time, a very attractive material and highly decorative from within the room, as well as out of doors, it has proved quite satisfactory for awnings.

If we go back to the origin of this particular product, we find it was used originally in corrugated metal buildings. Now, you who are architects and construction engineers probably are not too enamored of corrugated metal buildings. They limit your application. In that type of construction it was found that fiberglass was particularly economical because of its ease of installation. Naturally, it was made to the shape that conformed to the pitch of the corrugated material, and could be installed in the same manner as the corrugated building or siding material. The result was daylighting which infused uniform light. And, there were many other advantages over conventional types of daylighting.

I should like to refer to a question which was placed before the last panel in regard to the cost of this material. When plastics are used as *direct* substitutes for conventional materials we have a cost relationship. But, if instead of being direct substitutes, *they do new jobs,* then we have no basis for comparing cost.

Suppose we compare the cost of a square foot of this product with the cost of glass, for example. We can buy window glass for 7 cents a square foot, or somewhere thereabouts. What do we pay for a square foot of this material? Well, more than ten times that—over 70 cents. However, gentlemen, consider that this particular product requires no special framing. It can be sawed. It can be nailed, screwed, or molded into place. You architects know better than I how much weight you have to allow for frames—how much for the glass itself. Here you have a very light-weight product which does not require special handling, is shatterproof, is a high diffusing agent, is attractive, and can be nailed into a building.

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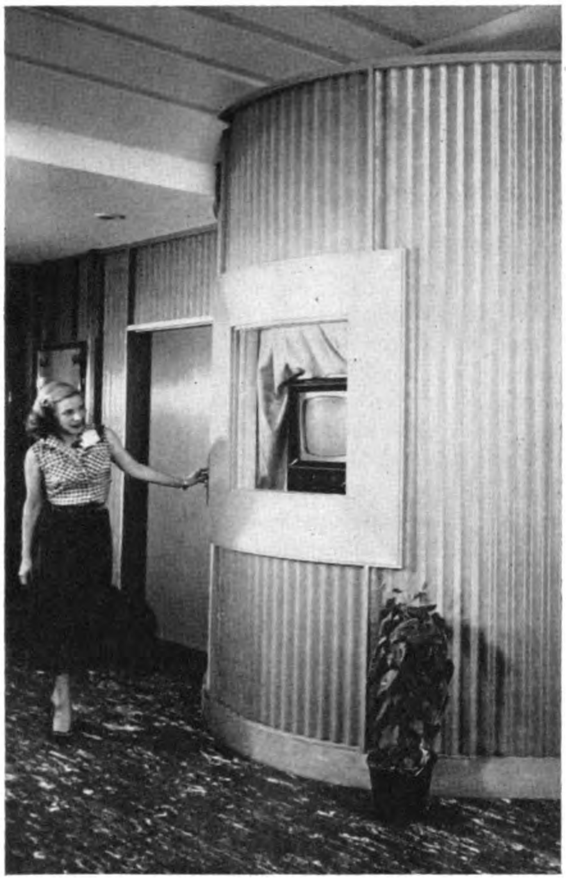

FIG. 2.1.1: Fiberglass-reinforced plastic corregated panel.

I would like to talk about color for just a minute. Today there is a great concern about the psychological effect of color. We have seen a great deal written in the past few years on what happens to a man psychologically when he is put in a green room, or a red room, or a blue room. We don't tell you what color to use—we are not psychologists—but we do know that *with these materials you have an unlimited range of colors.* You can bring the most desired color into a building, whatever that color may be.

The decorative uses of this product are almost limitless (Figure 2.1.1). Do you want a panel that will decorate in color integrally? That can be done. Do you want hollow white walls where your lights are actually within walled sections? That can be done. Do you want diffused lighting for utilitarian purposes in a machine shop, for example, where you must have uniform lighting? That can be done. Do you want an application such as awnings for both decorative and utilitarian purposes? That can be done.

While this is a very new product, I think it is safe to assume that there will be more than 20 million feet of this material installed in construction around the country this year. Seven or eight years of experience have served to point up both the advantages and the problems.

There are, today, a number of good manufacturers who have spent considerable effort, time, and money on the development of sets of physical data relating to this product, and I would like to refer to that for just a few moments. We have heard some highly technical discussions as to the strength characteristics of plastic materials this morning. I would prefer to look at what happens when these products are in place. How do they perform under the simple physical requirements that must be considered?

We have here a reinforced product with a tensile strength of somewhere around 15,000 psi. That is coupled with flexual strength of around 24,000 psi. What does that mean? It means that this material has a load-bearing characteristic—on approximately a four-foot span with conventional fasteners—of more than 100 pounds per square foot. That means it is adequate for roof installations where the failure point need not be considered beyond that approximate square footage. With a load requirement of 40 to 50 pounds, you have a safety factor of two—which is good.

While we have reasonable permanence in this particular field, backed up by good performance records, there are complaints; some of them come across my desk periodically. Most of these complaints have to do with what we would consider improper application.

Now, there is no question but that a very high light transmission means transmission of heat. Light energy, essentially, is heat energy. It is possible, by proper ventilation, by proper application, to reduce the heat factor to a point where it is not a great concern. If you shoot for 85 per cent light transmission, which can be had with a particular product, you are going to have heat troubles—no question about it. However, these problems, as I say, must be met by proper application. Remember, you don't require 85 per cent light transmission. If you had 85 per cent of direct sunlight coming into a building over the entire building, you wouldn't be able to read a paper without an eye shade and dark glasses. You wouldn't like it.

The glass people have done a great deal toward laying out the percentages of roofs which must necessarily be lighted. A glass skylight will permit a very high light beam to come into a building. But if you have a black floor, and this beam of light is absorbed on the floor, then you have a very dark perimeter.

This plastic material, on the other hand, has a very high diffusion factor. So we can reduce the amount of light brought into a building but diffuse it uniformly within the enclosure and thus achieve the lighting characteristics which we desire (Figure 2.1.2).

Let me review briefly some of the points I have

FIG. 2.1.2: Light diffusion is uniform with plastic ceiling

mentioned. In the matter of cost, we might say, "Cost compared to what?" In other words, you are doing things with this particular material that you can't do with other things. Therefore we must consider the cost in place or cost in use, not the cost per pound or the cost per square foot. This is particularly important in this field because this product can be handled readily on the job. It requires minimum support. It does not require special framing.

By the same token, you should remember that this is not an all-purpose material. It cannot be used for everything and anything. However, within its field it offers advantages over any other material, to my knowledge, that has been available to date.

We are going to have a discussion a little later by Dr. Pierson on the use, particularly, of acrylic in similar fields; so I am taking the liberty of passing over that aspect of light-transmitting panels.

The original application of this product was skylighting. However, that is becoming more and more only a portion of the field of aplication. We have seen in the last three years the growth of this material in the awning industry, and I believe it will continue to expand in that field.

There is a new field for this material which has just been touched to date, and that is the field of shower doors and tub enclosures. It is my opinion that this is going to be one of the largest applications for this material. It has many advantages inside the home. First of all, it is shatter proof and its use will help to cut down the number of accidents in the home.

One last word: Remember to examine these plastic materials carefully from the standpoint of proper application. We in the industry do not want to encourage the use of materials where they do not belong. By the same token, we hope that you will give us the opportunity to serve you in a manner which will take advantage of the quality which we do have to offer. Thank you.

GLAZING AND INTERIOR ILLUMINATION

By Orville L. Pierson*

Rohm and Haas Company

LIGHT-TRANSMITTING plastics are being used in the building industry for a number of other purposes in addition to the light-transmitting panels which were discussed by Mr. Berkson. The panels came into wide use more rapidly than other applications because they could be substituted easily for opaque materials and often could be installed by the same methods used for other materials.

Other light-transmitting uses of plastics have required the development of "packages" which simply could be specified by the architect and easily obtained and installed by the builder. Lighting fixtures are an elementary illustration of this type of use but are considered beyond the scope of this conference since they are so readily available and normally are installed as a kind of accessory to a finished building.

The outstanding light-transmitting uses of plastics are in skylights, glazing, and luminous ceilings and facades. These applications also illustrate different stages in the development of plastic uses in the building industry. One-piece dome skylights have become very well established and are available from a large number of manufacturers in packages ready to set onto the curbs. Window glazing ranges from the simple substitution of flat plastic panels for glass to a number of ideas which are still under development where the additional properties of plastics may be used to create new and attractive effects for the control of daylighting. Luminous ceilings also have progressed to the package stage, but store fronts or facades remain largely a custom business.

PROPERTIES OF PRINCIPLE PLASTICS USED FOR GLAZING AND ILLUMINATION

Three basic types of plastics are used for these purposes: acrylics, vinyls, and glass-reinforced polyesters. The general properties of these materials are shown in Table 1 which has been abstracted from the book, *Technical Data On Plastics*, published by the Manufacturing Chemists Association, Inc. The table also shows 1954 prices for the base resins as quoted by *Plastics World*. It should be noted that these costs are essentially per pound of raw material and that the processing and conversion costs—to be added before a finished item is ready for the building contractor—will vary widely. Additional costs will be discussed in conjunction with each of the applications.

ACRYLIC PLASTICS

The outstanding properties of the acrylic plastics are their excellent resistance to weather and their great clarity. The weather resistance is dramatically demonstrated by the use of cast acrylic sheets for aircraft glazing, including cockpit enclosures on the high-altitude fighters. It has also been demonstrated by many years of satisfactory performance in the building industry.

The water-white transparency of the basic material permits unusually high light transmission when acrylics are used in the clear form. It also permits a full spectrum of colors ranging from neutral gray tints for glare control to diffusing translucent colors of interest in ceilings, facades, and in some cases for skylights. Special compositions of the acrylics can transmit more ultraviolet light than normal glass glazing.

The material in the cast sheet form is available in construction industry sizes up to about 8 feet by 10 feet and in thicknesses ranging from 1/16 inch upward. It is also available as a molding composition which may be converted to sheet form by extrusion or to a wide variety of special shapes by injection molding. These latter uses are typified by automobile tail lights and parking light lenses which again demonstrate the outdoor nature of the material. Being a thermoplastic, the material is readily formed into the shapes required in building. Thus, a dome skylight can be made from a flat cast sheet of acrylic by simply heating it, clamping it around the periphery, and blowing it to the required height much in the fashion of inflating a rubber balloon. This thermoplastic property also leads to some limitations in use, but reference to Table 1 will show that the heat distortion temperatures or allowable service temperatures are satisfactorily high for building use even in the tropics.

Like all of the organic plastics, the acrylics have relatively large coefficients of thermal expansion. It is necessary in making installations with them to make

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TABLE I

PROPERTIES OF PLASTICS FOR LIGHT-TRANSMITTING USES IN BUILDINGS

KIND OF PLASTIC	Specific Gravity	Luminous Transmittance %	Thermal Expansion Coefficient: Max./°C.	Flamability Under .050" Sq. In./Min.	Flammability Over .050" In./Min.	Water Absorption: 24 hr. — %	Effect of Light	Max. Recommended Service Temp.: °F	Impact Strength Izod Notched ft. lbs./in.	Structural Stress at Fracture: psi	Tensile Stress at Fracture: psi	Flex. Modulus (apparent) psi	Resin Price, 1954 $/lb.
ACRYLIC Cast Sheet (Heat Resistant)	1.18 to 1.19	91 to 92	.0009	NA	0.5 to 2.5	0.2 to 0.4	Slight	180 to 200	.04	15,000 to 17,000	8,000 to 10,000	400,000 to 500,000	NA
ACRYLIC Molding Powder (Heat Resistant)	1.18 to 1.19	91 to 92	.0009	NA	1.0 for ¼" thick	0.3	Slight	185	.05 (Molded)	15,000 to 17,000	8,000 to 10,000	450,000	.70 to 1.00
POLYESTER (Reinforced with Woven Glass)	1.65 to 1.90	NA	NA	NA	0.5 to Self-Ext.	0.1 to 0.7	Slight	—	13 to 19 (Edge)	36,000 to 70,000	30,000 to 46,000	2,000,000 to 3,500,000	NA
VINYL General Purpose Unfilled	1.15 to 1.35	NA	NA	.04 Self-Ext.	.02 Self-Ext.	0.4 to 0.7	Eventually Darkens	140	NA	NA	1,400 to 3,000	—	.48½ to .58

NA means not available.

Physical properties were extracted from "Technical Data on Plastics," Manufacturing Chemists' Association, Inc., October 1952. Prices are from the August, 1954, issue of "Plastics World."

adequate provision for expansion and contraction, particularly since they are often used in very large sizes. In general, this creates no severe problems so long as the architect or builder is aware of this property.

The acrylics also offer good strength properties, such as tensile, impact, and flexural, as may be seen from Table 1. However, care must be taken not to overwork them lest they show signs of distress in the form of a very light surface checking known as crazing. Allowable working stresses for continuously imposed loads are in the range of 1500-2000 psi. Under many conditions loads such as these may result in an undesirably large deflection, and hence the long-time deflection, or cold flow, of the material should be investigated. Normally, these problems are avoided when using thermoplastics by shaping the material to rigidize it, as in corrugated sheet or in the dome skylights.

VINYL PLASTICS

The vinyl plastics are generally not recommended for long-term use when subjected to outdoor exposures. Their outstanding properties are an extreme toughness, which permits their use in very thin sections, and their self-extinguishing nature after ignition.

The vinyls are, like the acrylics, thermoplastic and so may be processed by the same general methods. Production of the very thin sheets—the most common form in which the material is used in buildings—is, however, usually accomplished by rolling the material in calenders. The thin sheets are then normally corrugated to provide sufficient rigidity. Custom-formed shapes may, of course, be readily produced from the material. Basically, the vinyl is transparent but it is normally used as a white translucent sheet to provide good diffusion of artificial illumination.

FIG. 2.1.3: Plexiglas dome at Princeton University

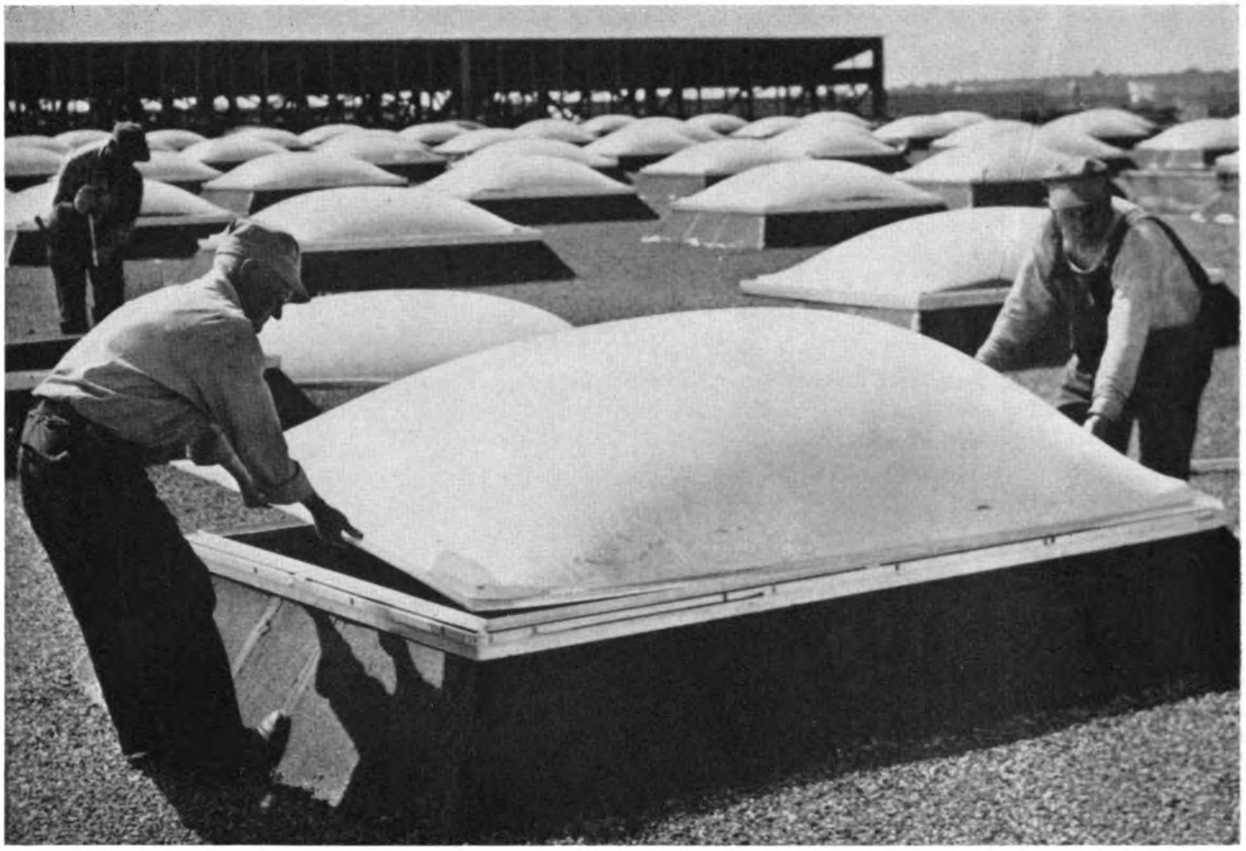

FIG. 2.1.4: Plexiglas skylight domes, each 62 by 96 inches

POLYESTER PLASTICS

The third of the light-transmitting plastics with which we are presently concerned are the polyesters. These materials are normally used with a fiberglass reinforcement and have been discussed in complete detail by others at this conference. They are characterized by great strength, derived from the glass reinforcement, and can be made in a variety of custom shapes and sizes. They offer good weather resistance, but with some minor trouble from erosion which exposes the glass reinforcement. At present the polyesters are not available in a completely transparent sheet, since the glass reinforcement introduces a translucent effect. The widest use of these materials is in the form of corrugated panels, but some of the custom shapes have been used, at least experimentally, in skylights, windows, and ceilings.

SKYLIGHTS

The one-piece dome skylight is an outstanding example of the adaptability of plastics to the requirements of the building industry. This development was started by the Rohm & Haas Company as early as 1946, but it has not been until recent years that the skylights have become widely used. They offer the advantage of a skylight enclosure which is entirely in one piece and thus leakproof. Since the units require no supporting frames, they admit substantially more light to the building through a given size of opening. Where desirable, they may be made in a translucent acrylic sheet, thus diffusing the light more completely within the building.

Despite these outstanding advantages, the development of the plastic skylight moved quite slowly until completely packaged units were made available by building supply people and fabricators. These units are now supplied to the trade with the flashing and edge attachment already mounted to the acrylic sheet. At present a number of fabricators and manufacturers, well distributed across the country, are offering these packaged units. Their light weight usually permits one man to handle them during the installation, although some of the very large-sized domes, such as 5 feet by 8 feet, require two men. Installation normally consists of dropping the unit over the prepared curbs and fastening it in place. The amount of on-site labor required is, therefore, substantially less than usual.

These dome skylights utilize some of the best properties of the acrylic plastics—i.e.: weather resistance, transparency, shatter resistance, availability in large-sized sheets, and formability. Some development work has been done on skylight domes of other plastics, principally polyesters, and a good many other shapes

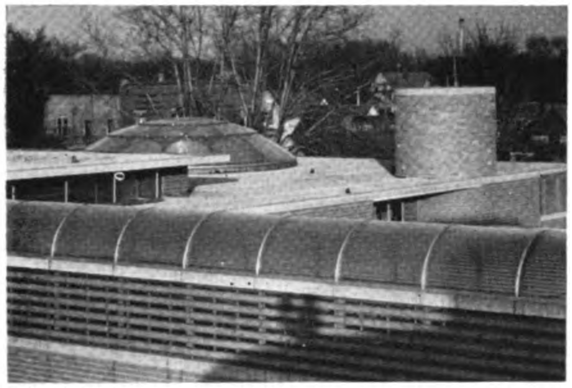

FIG. 2.1.5: Acrylic plastic Plexiglas as a corridor cover.

in addition to the simple domes have been used or tested. Thus, for example, corrugated sheets have been used as a glazing material for custom-built skylights ranging from nearly flat lights to steeply inclined glazing in saw-tooth construction. The acrylics, however, remain the principal material used for skylights primarily because the sheet is readily formed to desired shapes, even on a custom basis, and offers all of the other properties necessary for a long-lived installation.

Figure 2.1.3 illustrates one of the larger-sized, custom-fabricated skylight domes. This installation was made during the earlier development work and is used by a university to create shadow effects on architectural models located below the dome. Figure 2.1.4 shows an installation of the larger-sized, commercially fabricated skylight domes nearing completion. It will be noted that the flashing and edge protection has been attached to the curb and that the plastic dome is being set into place.

The plastic materials have been rated as slow burning and so have been approved by insurance laboratories. However, experience has shown that it is desirable to protect the edge of the plastic dome by metal, thus providing some degree of fire resistance should a fire spread across the roof. The attachment methods have also been worked out to provide for constant drainage of condensate to the exterior of the building while making adequate provision for expansion and contraction of the plastic dome.

Among other variations involving the use of the plastic skylight dome are ventilators or fans in a prefabricated curbing ready for installation of the roof. Accessories have included ceiling domes, usually made of a diffusing material and mounted level with the interior finish of the building.

Since the acrylic plastics are readily formed to special shapes, considerable development work has been done to evaluate such shapes for skylight use. Some evidence has been collected to indicate that a deeply formed dome—approaching a hemisphere—

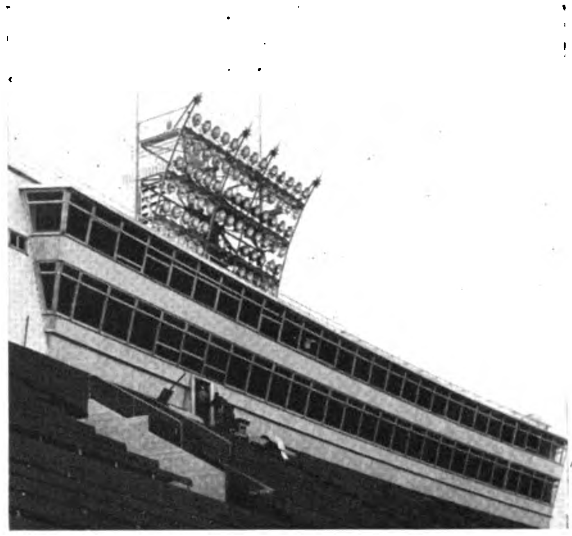

FIG. 2.1.6: Acrylic glazing fulfills safety requirements

actually will gather more light into a given opening than would pass through the unglazed opening.

Another special shape developed for custom use is shown in Figure 2.1.5, where the acrylic plastic has been employed as a cylindrical top for a corridor and also as a very large multipanel dome. The installation illustrated is on the S. C. Johnson Company research building designed by Frank Lloyd Wright. Here the acrylic sheet has been engaged in metal channeling to provide for necessary expansion and contraction and is employed as the weatherproofing medium over roofs constructed of glass tubes.

PLASTICS FOR GLAZING

Increasing quantities of plastics are being used for glazing, in many cases as a substitute for glass. Although the plastics are markedly higher priced than glass, they have proved to be economical in areas

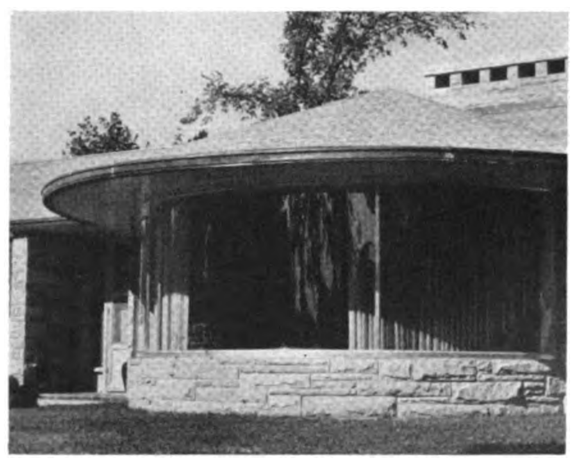

FIG. 2.1.7: Plexiglas acrylic plastic sheets were formed on the site to the required curvature.

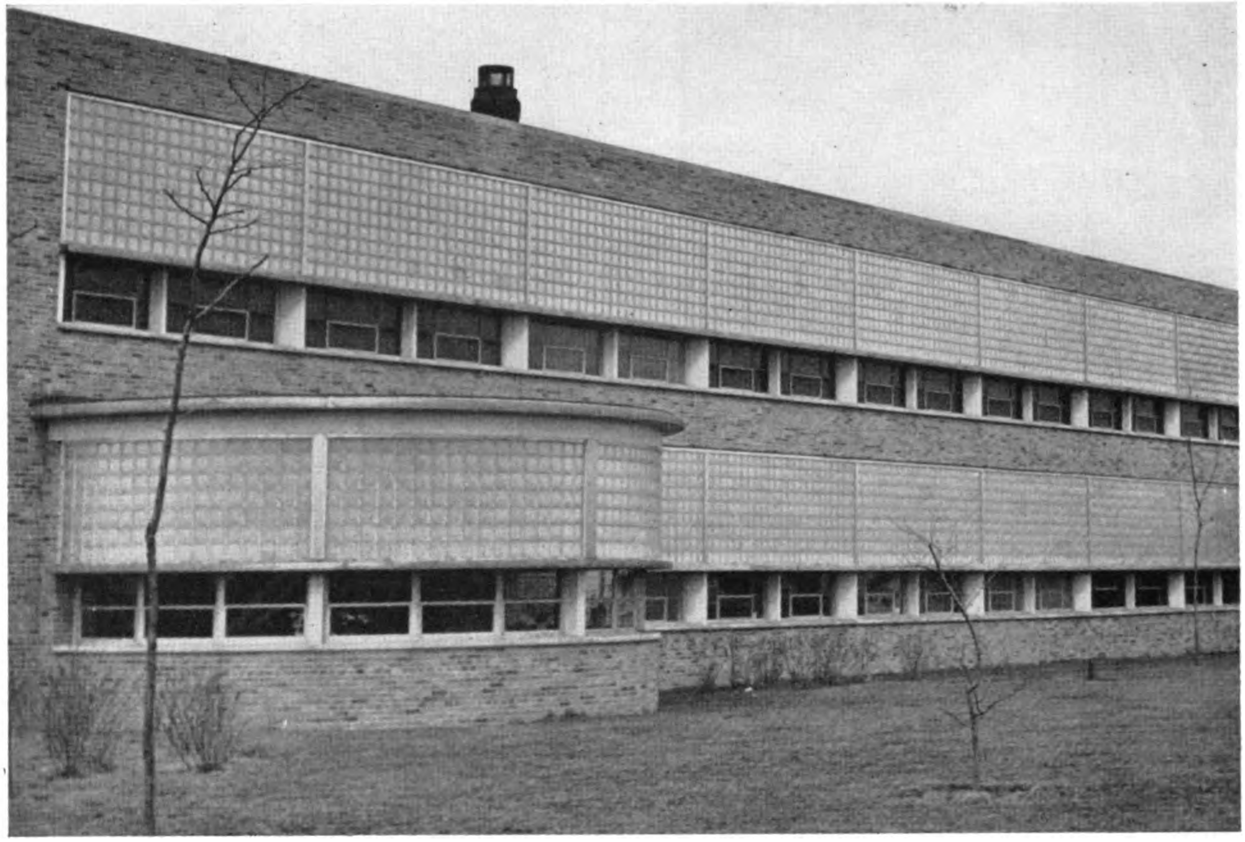

FIG. 2.1.8: Transparent neutral gray acrylic plastic window panes cut glare, guard against playground breakage

where there is a rate of high glass breakage, since the shatter resistance of the plastics cuts the need for replacements and eliminates the attendant labor cost. The material used for this purpose is primarily acrylic sheet, in its natural transparent state or tinted, translucent, or patterned to provide an effective control of glare. The reinforced polyester sheet is becoming available as a flat material for this purpose and has been used in some installations. Distribution of these materials is rapidly improving, and material for glazing can now normally be bought over the counter from plastic shops in most metropolitan areas.

When the plastic is used in relatively small panes, it can be set in a sash in much the same manner as window glass, and some of the permanently soft glazing compounds can be used. As the size of the pane increases, however, more careful consideration must be given to installation methods. Thus, for panes larger than two feet square, glazing beads or other similar channel methods of installation are recommended. While sizes as large as four feet have been successfully installed in some types of commercial sash, normally these sash do not provide a satisfactory edge engagement. Special methods have been developed to adapt the standard sash where it is desirable to use it with plastic glazing.

Figure 2.1.6 shows a large installation of flat acrylic glazing where shatter resistance and safety were among the prime considerations, since it was considered undesirable to locate large areas of glass over the heads of the spectators in the stadium. The light weight of the acrylic glazing—less than half of glass—was also an important factor, making the sliding sash easier to operate.

Figure 2.1.7 shows a residential installation of acrylic glazing where the plastic sheets were formed on the site to the required curvature. This may be done safely as long as the radius of curvature exceeds 180 times the thickness of the sheet. In this particular case the use of the plastic sheet effected a marked saving in comparison with custom-formed glass.

Flat acrylic sheets are being used increasingly for glazing in school buildings. Here they contribute not only the shatter resistance needed to protect against breakage in playground enclosures but also provide glare control through the use of tinted or diffusing materials. The use of the transparent neutral gray for glare control in a Detroit school is illustrated in Figure 2.1.8. This school has employed the plastic vision strips in conjunction with glass block.

The best use is made of the plastic glazing materials when they are formed in shapes especially suited to the purpose. This point was illustrated in the discussion of skylights, for which the doming of thermoplastic materials produces a part ideally suited to the need. The same general architectural concepts are being extended to sidewall glazing where the forming of the plastic material is introducing a new three-dimensional look. Figure 2.1.9 shows one application of specially formed glazing to the upper portion of a school gymnasium in Philadelphia. A specially formulated, blue-tinted, translucent acrylic sheet was used to form the V-rib panels. Since these panels are flat around their periphery, they can be easily installed in channel-type mountings. The forming in this case was done to add an interesting texture to the building exterior as well as to rigidize the plastic sheet, thus permitting the use of a thinner, less expensive material.

Other installations have used simply domed panels for the replacement of multipane steel sash in industrial locations where corrosion of the steel has been a serious problem. Obviously, a great many other shapes and textures can be readily created wherever the architect or builder wishes to employ glazing to harmonize or contrast with the other building textures.

In addition, the forming of the plastic glazing panels offers an unusual possibility for built-in sunlight control. For example, one side of the ribbed surfaces shown in Figure 2.1.9 could be opaqued by application of plastic coatings, thus admitting only northern or general sunlight to the building. Research into the full possibilities of these large one-piece Louverlite glazing panels is now under way in the Rohm & Haas laboratories. Data are being collected on the light distribution within when various designs of these acrylic panels are used. Some work has been done with special shapes of reinforced polyester plastics. To date, this work has been limited to coffer-like panels shaped primarily to rigidize them, thus permitting glazing of a large opening with relatively thin sheet.

An intriguing development possibility lies in prismatic panes which might be either extruded or molded from the thermoplastic acrylics. The molding process can easily produce a far more precise optical system than is practical in cast glass. Thus, acrylic panels could be designed and produced in thin sections to effect very good control of sunlight entering the building. Precisely molded prisms could be designed to direct the sunlight to the upper portions of the room, where it could be spread through the room to provide a satisfactory distribution of daylight. These panels could be quite thin, in contrast with glass block, and could be readily installed in standard metal or wood sash. The use of two panels, prismatic surfaces face to face, would avoid the problem of how to clean the prismatic surfaces and at the same time provide insulating values in the window. The practicality of such optical systems in thin sections was established some years ago with the development of production methods for magnifiers used on small television screens. It will be recalled that, for this purpose, lenses were molded into the acrylic sheet which had the end appearance of a phonograph record and yet provided the same magnification achieved earlier by extremely thick lenses.

FIG. 2.1.9: Example of special forming of plastic glazing.

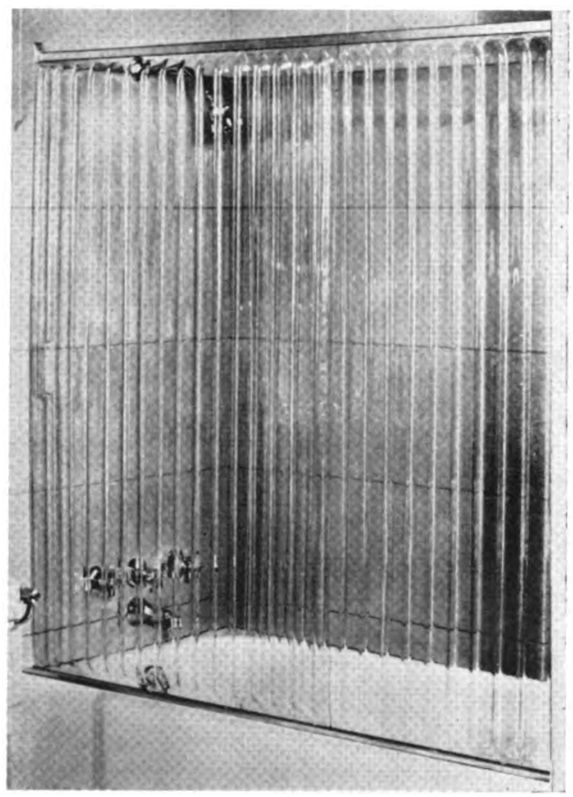

FIG. 2.1.10: Rigidized tinted acrylic sliding shower panel.

The use of the formed acrylics has made possible some new concepts in the solution of interior archi-

FIG. 2.1.11: Plastic railing has decorations accented by edgelighting

tectural problems. Shower curtains have been replaced with sliding panels rigidized from tinted acrylic sheet as shown in Figure 2.1.10.

The acrylic plastic sheets have also been widely used for unusual decorative effects in interiors. Figure 2.1.11 shows a railing in a Dallas theater which has been decorated by curving the surfaces of the plastic, and has the decoration accented by edgelighting. The unusual clarity of the acrylic plastic makes it possible to introduce the light into the material along any edge of the sheet. Decorations applied to the sheet surfaces—carving, painting, or scribing—glow attractively when so lighted.

LUMINOUS CEILINGS

The availability of large, lightweight, shatter-resistant, plastic sheeting has made practical the even illumination of the entire ceiling in rooms. Such lighting virtually brings the outdoors inside by producing shadow-free, glareness illumination at very high levels. The plastics used here have been either very thin vinyl sheeting of the .007-inch thickness range, or acrylic sheet. The vinyl is normally corrugated, thus rigidized sufficiently for use in spans up to 36 inches, and is available in rolls as long as desired.

The acrylic sheet has been used in thicknesses in the .020-inch range when produced by a special process which toughens it by orientation of its molecular structure. This material is at present limited to about 24-inch widths, and larger sections of acrylic use the standard production processes with thicknesses usually in the 1/8-inch range and sizes up to five feet square. For the larger-size sections, the acrylics are rigidized either by corrugation or by forming into special custom shapes suited to the architectural decor. The acrylics are also available commercially in standardized coffer sections suited to mounting in either metal or wooden supports.

Both the vinyl and the acrylic ceilings may be specified as complete packages, including the electrical installations. Systems have also been worked out whereby the plastic ceiling may act as the inlet for conditioned air. Sound-absorbing baffles often are added to the ceiling, or in some cases sound conditioning is achieved by areas of sound-absorbing ceiling surrounding illuminated areas.

Costs of these plastic ceilings have ranged upward from $3 per square foot including the electrical installations. In comparing this cost with other types of lighting, it should be noted that the plastic ceiling normally comprises the entire ceiling finish and can thus save substantially on the construction cost. In many cases of remodeling, luminous plastic ceilings

FIG. 2.1.12: Flat acrylic sheet for diffused ceiling lighting.

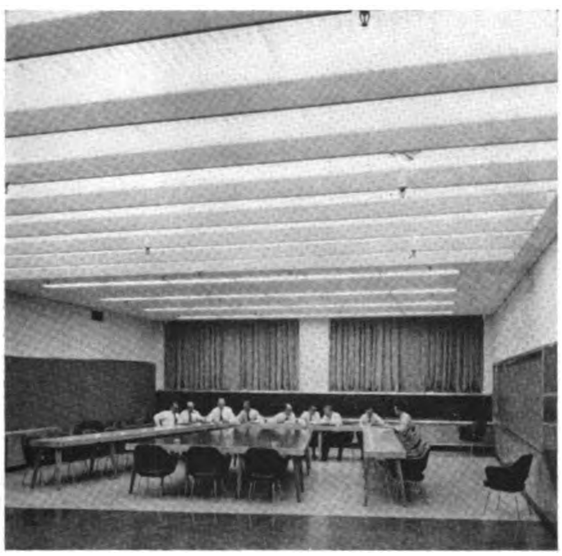

FIG. 2.1.13: A commercially available package ceiling installation.

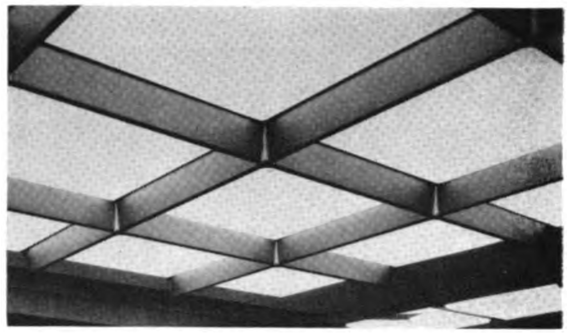

FIG. 2.1.14: Plexiglas ceiling with acoustic baffles

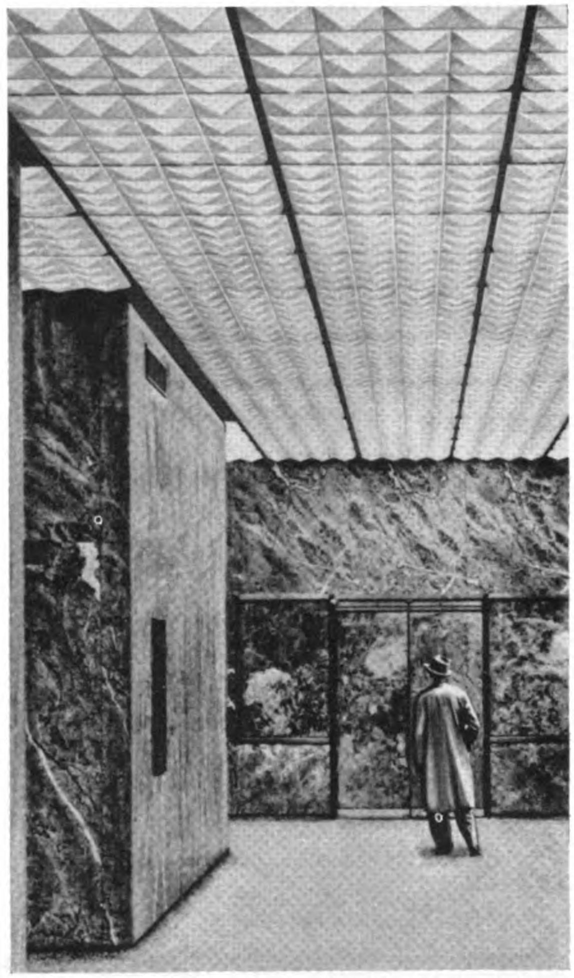

FIG. 2.1.15: Example of design possibilities with Plexiglas acrylic plastic for ceilings.

have been used to conceal a maze of piping and ducts, thus achieving a clear interior with outstandingly good lighting at a low over-all cost.

Some use of plastics, particularly the vinyls, has been made in egg-crate ceilings. Generally, these installations have not proved as satisfactory as the ceilings employing diffusing plastic panels. The principal reason for the preference for the diffusing panels has been that the egg-crates permit reflection of the bare tubes on articles located directly below the light sources. This reflection is particularly troublesome on drafting instruments or on the keys of business calculating machines.

Figure 2.1.12 shows an installation of flat acrylic sheet as the diffusing medium in a ceiling for a powerhouse control room. Generally, the flat sheets

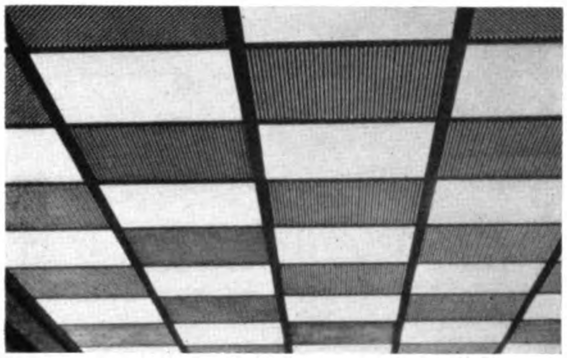

FIG. 2.1.16: Another deign using alternate squares of perforated metal and plastic diffusers.

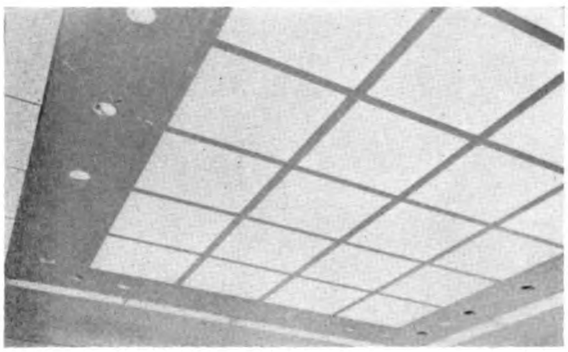

FIG. 2.1.17: White translucent Plexiglas covers fluorescent lights; spotlights for accent lighting.

FIG. 2.1.18: Outdoor acrylic installation in use since 1948.

FIG. 2.1.19: Store front of corrugated acrylic sheets

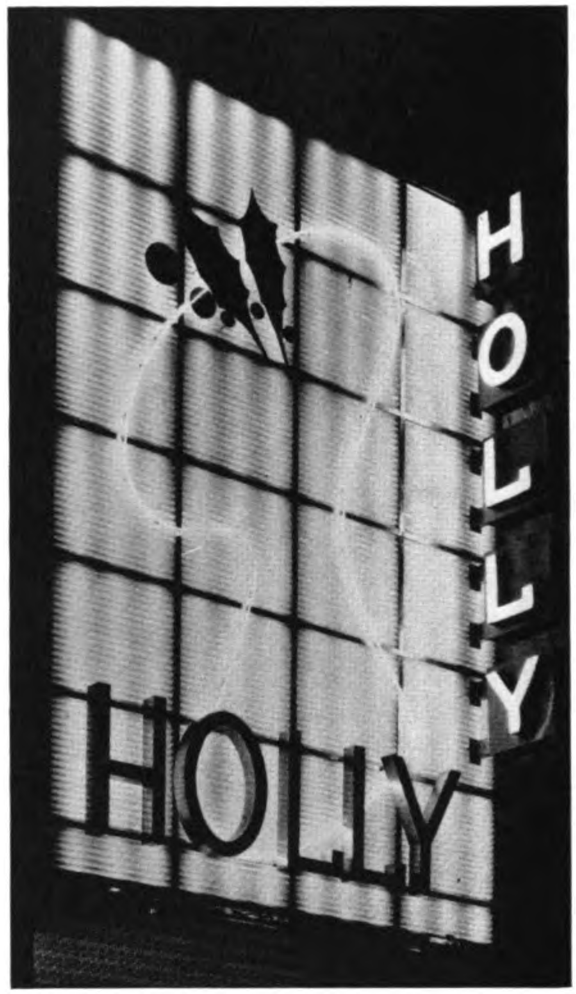

FIG. 2.1.20: Decorative Plexiglas store front

are not used since it is necessary to use rather thick sections to avoid an objectionable sag in the sheet or else limit the spans to modules as small as two feet. Rigidizing of the sheets by corrugating permits spans up to four feet, and also introduces textural possibilities. The corrugation also permits admission of ventilating air through the spaces at the ends of the corrugation, since the plastic sheets are usually supported by T-sections with clearance between the web of the T and the ends of the sheets.

One of the commercially available package ceiling installations is shown in Figure 2.1.13. This installation employes corrugated acrylic sheet, but the corrugated vinyl sheeting is often used in similar installations. In Figure 2.1.13 the acoustic baffles used for sound conditioning also permit easy installation of sprinklers below the plastic ceiling. Further sound conditioning has been achieved by strips surrounding the ceiling and covering the upper portion of the walls of the room.

The use of standardized coffer sections is illustrated in Figure 2.1.14, where they have been employed in a five-foot module. Another demonstration of the design possibilities of the easily formed thermoplastic acrylic sheets may be seen in the Pittsburgh Gateway Center corridors shown in Figure 2.1.15. Many other decorative techniques are possible as, for example, use of alternate squares of perforated metal in Detroit's Sheraton-Cadillac Hotel, shown in Figure 2.1.16.

Use of luminous ceilings in some cases produces such a uniform or bland lighting that accent lighting may become desirable. One method of achieving such accent lighting is shown in Figure 2.1.17, where incandescent spotlights have been built into the ceiling at the Museum of Fine Arts in Boston. The spotlights not only provide the accent but also permit mixing their warmer light with the output of the fluorescent tubes normally used in luminous ceilings. In some cases luminous ceilings have, in fact, become true skylights in roofs. In these cases addition of artificial illumination between the plastic ceiling and the skylight carries the daylighting effect on into the night time.

The luminous ceiling concept has been carried outdoors in the application of luminous facades to store buildings. Figure 2.1.18 shows the historic installation of an acrylic illuminated store front made by Food Fair in Atlantic City in 1948. At the time of its installation this was probably the largest plastic item ever made, but it has since been entirely overshadowed. It has continued in satisfactory service since its installation and so has given considerable impetus to the outdoor use of acrylic sheet. The above-mentioned installation employed custom-formed sections to create the effects shown in the photograph. Many subsequent developments, such as the Edison store front shown in Figure 2.1.19, employ corrugated acrylic sheets which are now available for widely distributed suppliers.

The possibilities of combining illuminated plastic sheet with other materials and of making the lighting and integral part of the design are illustrated in Figure 2.1.20, where diffusing panels permit bright lines of the light sources to carry through. Reinforced polyester sheets have been used in store fronts to a limited extent but in many cases have not been as satisfactory as the acrylics since the presence of the glass reinforcement makes it impossible to achieve the same uniformity of color and light distribution.

GENERAL DISCUSSION

MR. HUNTZICKER: We are going to have Mr. Berkson and Dr. Pierson participate in a short discussion, which will be moderated by Mr. C. L. Crouch, Technical director of the Illuminating Engineering Society of New York City. Mr. Crouch is a graduate of the University of Michigan with a Bachelor of Science degree in Electrical Engineering. He is a member of the Optional Society of America, has been employed in the past as an industrial lighting consultant and as an illuminating engineer. He is the author, or co-author, of many attendant articles on lighting and illumination. Mr. Crouch.

MR. CROUCH (Moderator): Mr. Chairman, speakers, friends: We are happy that the illumination field is being properly considered in relation to plastics. I see, also, that there is a noticeable sprinkling of the competitive glass industry here; so we may have an interesting time in the next few minutes.

We are happy to think of what plastics contribute to the illumination field, because we feel they can make a real contribution and, indeed, have already made an outstanding, almost a revolutionary, contribution. You have probably seen some of those revolutionary developments and, as you go on into fixtures, you will see a tremendous development in that phase, also.

Just as a little basis for our thinking here as engineers in the illumination field, let me say that we are coming to realize that we are concerned, not merely with illumination on a job, but with the whole luminous environment and its impact on the human organism. We see to feel, and we feel to see, and so all of our psychological reactions, our emotional reactions, and our human performance are dependent on this total luminous environment. In other words, we are inclined to extrapolate somewhat and say that the acoustical aspects of that same environment, and thermal action, all combine to give livability and performability to the complex human organism.

So, while we are thinking of this medium, it is not just a matter of how much electrical current can be turned on but what brightness balance can be produced. Sometimes that means cutting down the amount of light or amount of brightness that nature gives us, or redirecting and controlling it in such a way as to produce the desired effects.

Now, can we think in terms of the functional requirements and have some questions also regarding the mechanical characteristics?

MISS MARILYN GRAYBOFF (ARCHITECTURAL FORUM): I have a question about glazing and also one about skylighting. I have noticed that, with few exceptions, standard glazing techniques that have been developed for glass are used. Would it be possible in the skylights to mold an integral flange on a skylight to eliminate the metal so that it could be directly flashed to a roof? And in the glazing with polyester panel, wouldn't it be possible to work up details that could be sent out to architects showing the application directly to rough framing or to masonry?

MR. CROUCH: That's a long question. The thought is, can we develop the product with flanges and with accessory arrangements that will provide easy usefulness of the materials? Did I capture the thought of it?

MISS GRAYBOFF: Well, more than just easy application. Make the material work to full advantage, make the plastic work as its own framing, if possible, rather than using metal framing that has to be developed to support it.

DR. PIERSON: I would like to point out that this whole development started with self-framing. It would be quite simple to form a dome that would be entirely self-flanging to eliminate most of the metal contact. But there are certain good fire insurance reasons for not doing that. That is why we put metal in that place where a minimum of metal is used to provide fire-proofing around the edge. Also, it somewhat simplifies the attachment to the other roofing materials. John, do you want to comment?

MR. BERKSON: It is possible to treat both of these types of materials in a similar manner, as one might treat any other nailable or fastenable product. In other words, it is conceivable that one may install directly into the standard construction of the building using a panel of this material in conjunction with conventional materials, rather than with special framing. This is most common, of course, in metal buildings and can be done in built-up-roof buildings by simple framing in the required preparation for a stamping. However, it is possible to eliminate the problem of individual glazing of the sections of the window. Does that answer your question?

MISS GRAYBOFF: I understand that it can be used that way. I think architects realize it somewhat; yet, we still find that everybody, or almost everybody, uses conventional glazing framing.

MR. BERKSON: There are specific framing details available.

MR. JEFFREY E. ARONIN (Voorhees, Walker, Foley & Smith): I would like to ask Dr. Pierson whether it is possible to score acrylic light-transmitting panels in the same fashion that glass may be scored, so that, if they are used in laboratory windows or domes, they can be blown out by explosion.

DR. PIERSON: That can be done but not very satisfactorily. We feel that the better approach is to use a thinner section, which will permit the entire panel to snap out and at the same time leave an undamaged panel for normal use. Another innovation that has been used is a kind of a blow-out mounting using a spring-type of arrangement so that, with the flexibility and resilience of the plastic panel, the whole thing will snap out and can be set back in place.

MR. GUY G. ROTHERNSTEIN (Architectural Consultant, Progressive Industries, Inc.): I have a question concerning a building which was hit by a hurricane. If this building had been glazed with ordinary glass, would the hurricane have shattered the glass and the roof stayed in place?

DR. PIERSON: Fortunately, there happens to be a very complete answer to that. The building in question was a loading dock that was entirely open on the fourth side; so there was no question of build-up in this case.

MR. WALTER A. TAYLOR (American Institute of Architects): In our clinic service we have had claims about colorfastness of this plastic material in exterior use, and the dissent from colorfastness. Is there any reassurance today?

MR. BERKSON: There are standards being set up within the industry. I am sorry to say the standards have not been completed to date. The product is not entirely colorfast, but it is approaching that condition. It is fade resistant, to a point. Let's put it this way—where a known or standardized product is involved, you can expect reasonable colorfastness; where unknown or unestablished products are involved, it is very difficult to say, very difficult to know the pigments and the resins that were used.

MR. CROUCH: May I amplify that question to say: Is it possible to keep uniformity of color control in the plastic?

MR. BERKSON: That is a question for the paint industry as well. Reasonable uniformity has been obtained in color control.

DR. PIERSON: May I amplify that? One of the greatest problems with color is outdoor exposure in test stations, most severe of which is probably in the south of Florida. At present, in terms of some of the plastic materials in certain colors, it is possible to offer good assurance that you will have no noticeable or visible change in color over a period as long as five years in South Florida. It is necessary to be very careful in selecting the color to get the greatest stability. There are plastic materials that are designed for special color effects but they should be used only in interior applications or in cases where color stability would not be important.

MR. CROUCH: We hope to get more information on this across to you people. Can one of the gentlemen of the panel speak of the problem of cleaning and destaticizing the material in lighting fixtures?

DR. PIERSON: I assume that is intended to refer to the acrylic resins as well as to some of the other transparent materials. This has been a rather serious problem, because, as you people in the electrical industry know, good electrical insulators build up static charges. The industry's answer to this problem is to make available various antistatic waxes which can be applied to light shields or diffusers at the time they are installed and reapplied anytime they are taken down and given a thorough washing or cleaning. These waxes have been quite successful in leading off the static charge. Microscopic action keeps a little bit of moisture on the surface and helps to discharge the electrical accumulation. Generally speaking, in large areas static charge has not been too serious an obstacle to overcome.

MR. WALTER KUCHTA (Pace Corporation): I have a question for each of you gentlemen. Does Mr. Berkson intend to imply that the high-diffusion factor is available only in plastics, and does Dr. Pierson intend to imply that plastics only are suitable and available for play lights?

MR. BERKSON: It was not inferred that fiberglass reinforced plastics are the only reasonable material for diffusing light.

Dr. Pierson: I think we ought to point out that, with limited time, we can add only some brief remarks on the subject we are talking about. Such established people as the glass industry are completely well known to all of us. (Applause.)

MR. KUCHTA: I'd like to direct my questions to Mr. Berkson. What progress has been made to date in factors of glazing with the possible utilization of fibrous glass, both from the standpoint of weight and cost?

MR. BERKSON: These factors are not easy to describe specifically. The average weight of the material itself amounts to approximately eight ounces per square foot. Conventional supports are all that are required in the average factory installation. In other words, it is not necessary to supply specific framing for glazing. In small or flat panes, however, it would be necessary to use conventional framing methods. That means you would have the inherent weight characteristics of a glass installation and would lose part of the savings to which we referred earlier. As far as cost is concerned, the cost ratio to that of glass depends entirely upon the economies which may be effected on installation and on the replacement factor which would be apparent in instances where breakage is likely to occur.

MR. CROUCH: I am sorry, that is the last-question we can take at this time. We will now adjourn for lunch and will meet here at two o'clock for the afternoon program.

PLASTIC THERMAL INSULATIONS AND VAPOR SEALS

By R. N. Kennedy*

The Dow Chemical Company

IN addition to the usual durability and low cost requirements for a building material, a thermal insulation must have a low heat transmission rate—a K-factor of less than .50. Basically, plastics are poor conductors of heat and, in their expanded form, they meet the accepted values for thermal insulation. An insulation must also be resistant to the accumulation of water and ice, whether such resistance is achieved either by its own structure or by proper installation techniques. It must not decay or support fungus growth and it should be odorless. These requirements are inherent in many expanded plastic materials. The high strength-weight ratio of expanded plastics is a further advantage in insulation uses.

Most plastics have been expanded and, as such, may be classified as: (a) thermosetting or thermoplastic, (b) connecting or non-interconnecting cellular structure, (c) "pre-expanded" or "foamed-in-place." Many of the properties of expanded plastics—such as resistance to solvents, durability, burning characteristics, water resistance and heat resistance—are entirely dependent upon the base plastic.

As mentioned previously, several factors are to be considered in the selection of an insulation for the building industry. In addition to thermal conductivity, durability, and resistance to mold, rot and decay, the characteristics most often examined are:

1. Resistance to water (non-interconnecting cells)
2. Strength and toughness at low densities
3. Handling and installation (sizes available)
4. Cost
5. Odor
6. Flammability
7. Resistance to heat.

In the following chart, various commercially available expanded plastics are compared with respect to these factors. The numbers in the chart refer to the characteristics numbered above:

Plastic	Excellent	Satisfactory	Unsatisfactory
Polystyrene—P, R	1, 2, 3, 5	4, 6, 7	
Phenolic—E, R	6, 7	1, 4, 5	2, 3
Alkyd-isocyanate—E, R-F ..	1, 7	2, 5, 6	3, 4
Polyvinyl chloride—P, R-F ..	1, 6	2, 5, 7	3, 4
Urea-formaldehyde—P, R ...	5, 6	4, 7	1, 2, 3
Cellulose acetate—P, R	1, 5, 7	2, 3, 6	4

P: Pre-expanded; R: Rigid;
E: Expanded-in-place; F: Flexible.

Up to the present time, with one exception, these plastics have not been accepted as insulation in the building industry, primarily because of cost, but in a few instances because of insufficient structural strength or resistance to water. The exception—expanded polystyrene—has been used as low-temperature and comfort insulation for the past nine years. This material meets the requirements for an insulation. It is also low in cost because it is produced by continuous process from a low-cost plastic. It is expected that other expanded plastics will become accepted as costs are reduced through inproved technology of manufacture and larger volumes.

Expanded polystyrene is light in weight, 1.3 to 2.0 pounds per cubic foot. It has an average K-factor of .25, an average compressive strength of 3,000 pounds per square foot, has excellent water resistance with no capillarity, and negligible water vapor transmission. It does not rot or decay, is odorless, and is easily handled and installed. Expanded polystyrene is a very versatile material, finding application in many fields. It has been accepted as a low-temperature insulation in freezer and cooler spaces, refrigerated trucks and railroad cars, ships, domestic refrigerators, etc.

COMBINED USES, AT FIRST

Its first use, in the general building field, was approximately eight years ago—as a combination insulation moisture barrier and plaster base in masonry block homes. As a plaster base in masonry construction, expanded polystyrene boards are applied to exterior walls by means of low-cost Portland cement mortar. Plaster is applied directly to the boards, resulting in a construction which compares favorably in cost with the standard furring strip method and gives a wall with a lower U-factor and greater resistance to the passage of water vapor.

In Figure 2.2.1 you see boards being applied to concrete block wall. The uniform layer of Portland cement mortar is applied by means of a push-box. Figure 2.2.2 shows expanded polystyrene boards in place on the masonry wall of a home, ready to receive

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FIG. 2.2.1: Polystyrene boards applied to concrete block wall.

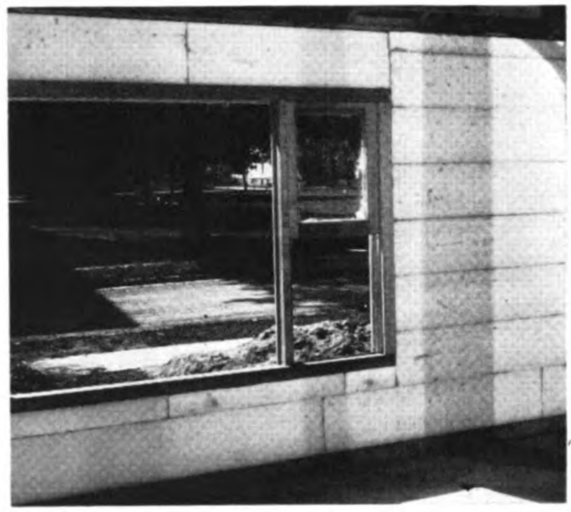

FIG. 2.2.2: Plaster will be applied directly on these expanded polystyrene boards.

the first coat of plaster. In cinder-block construction, this method results in a U-factor of .15 as compared to a U-factor of .27 for the furring strip method.

As perimeter and slab insulation, use of expanded polystyrene has been growing rapidly in the last few years because it maintains its K-factor by not absorbing water and will not rot or decay. The boards may be placed in the forms and the concrete poured directly against them or they may be adhered to the structure after the masonry is in place. An example of its use as slab insulation is shown in Figure 2.2.3. The boards are laid directly on sand fill, the reinforcing wire is laid in place and concrete wearing floor is poured directly on to the expanded polystyrene board.

One method of using perimeter insulation is shown in Figure 2.2.4. Here the boards are laid under the floor slab around the perimeter of the building. The insulation also may be placed on the inside or the outside, of the foundation. In this case, the boards are placed in the forms and the masonry poured directly against them or the boards are adhered to the masonry after it has been erected, as is necessary in the case of concrete-block construction.

The use of expanded polystyrene as a plaster base in masonry homes and as perimeter and floor slab insulation has been accepted by public housing authorities.

GOOD ROOF INSULATION

Expanded polystyrene is an excellent roof insulation. However, in this application, special techniques are necessary for build-up roofs. The heat distortion temperature of expanded polystyrene is lower than the application temperature of materials used for hot roof applications and the insulation must be protected to prevent thermal distortion. This has been done by applying a one-quarter inch layer of Portland cement mortar or by using one layer of roofing felt. The advent of cold roofing methods and improved techniques for hot roofs have broadened the application of expanded polystyrene in this use.

Figure 2.2.5 shows expanded polystyrene boards as roof insulation on a wood roof deck, and a layer of roofing felt as a protective medium against the

FIG. 2.2.3: Expanded polystyrene boards on sand fill with concrete poured over them.

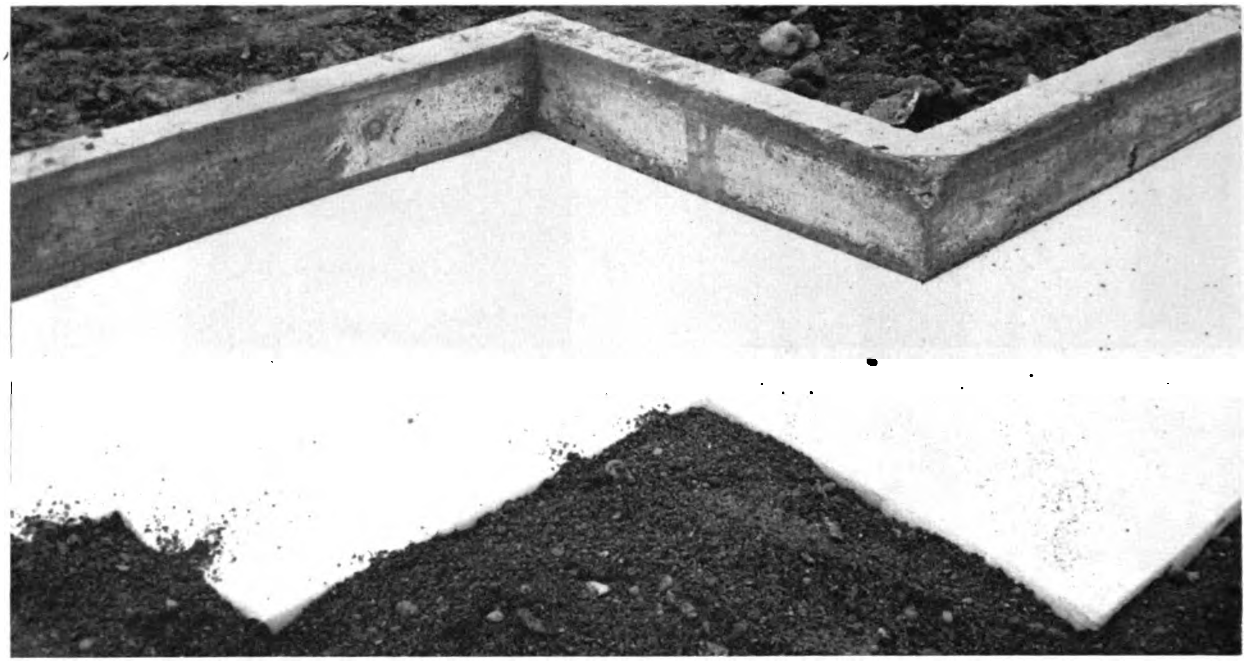

FIG. 2.2.4: Expanded polystyrene boards used in a perimeter installation

hot application. The felt is nailed through the insulation to the wood roof deck. Adhesives are required to apply the layer of felt when the deck is steel or concrete.

Figure 2.2.6 illustrates an unusual roof application, used in cold storage rooms. This method would apply only for roofs which need at least two two-inch-thick layers of insulation. Two layers of boards are laid directly on bar joints with Portland cement between the layers and on the top surfaces. This forms a sandwich construction of the top layer, resulting in strengths sufficient to meet the building code requirements for roof decks. A standard build-up roof is applied to the Portland cement layer on top.

FIG. 2.2.5: Expanded polystyrene boards on a roof installation

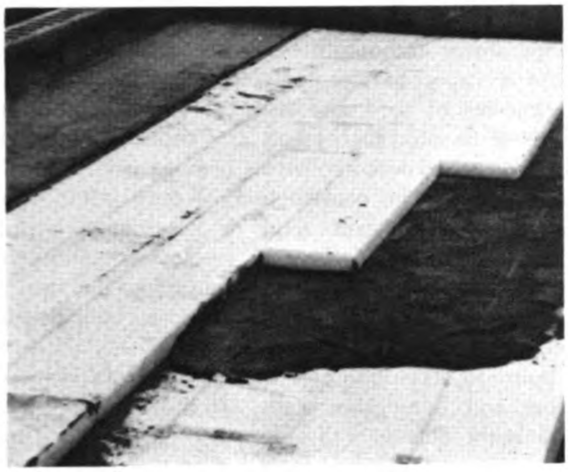

FIG. 2.2.6: Expanded polystyrene boards on roof construction; top layer forms a "sandwich".

FIG. 2.2.7: Expanded polystyrene boards on a load-bearing wall construction; concrete sprayed.

The use of expanded polystyrene as a core material in sandwich construction is in a relatively early stage of investigation. Panels with skins of concrete, plywood, metal, and fibrous glass, reinforced with styrene polyester, are being investigated. The high strength-weight ratio, low thermal conductivity and the water resistance of polystyrene make it a very interesting core material for construction of these types.

An interesting load-bearing wall construction using an expanded polystyrene core is shown in Figures 2.2.7 and 2.2.8. Boards are first placed against a temporary wood framework; then a one-inch layer of reinforced concrete is applied by spraying. The framework is removed and a similar layer is applied to the inside, resulting in a strong sandwich type of construction.

Condensation and moisture control have always been an important point in building construction and, with the increase in air-conditioned buildings, further

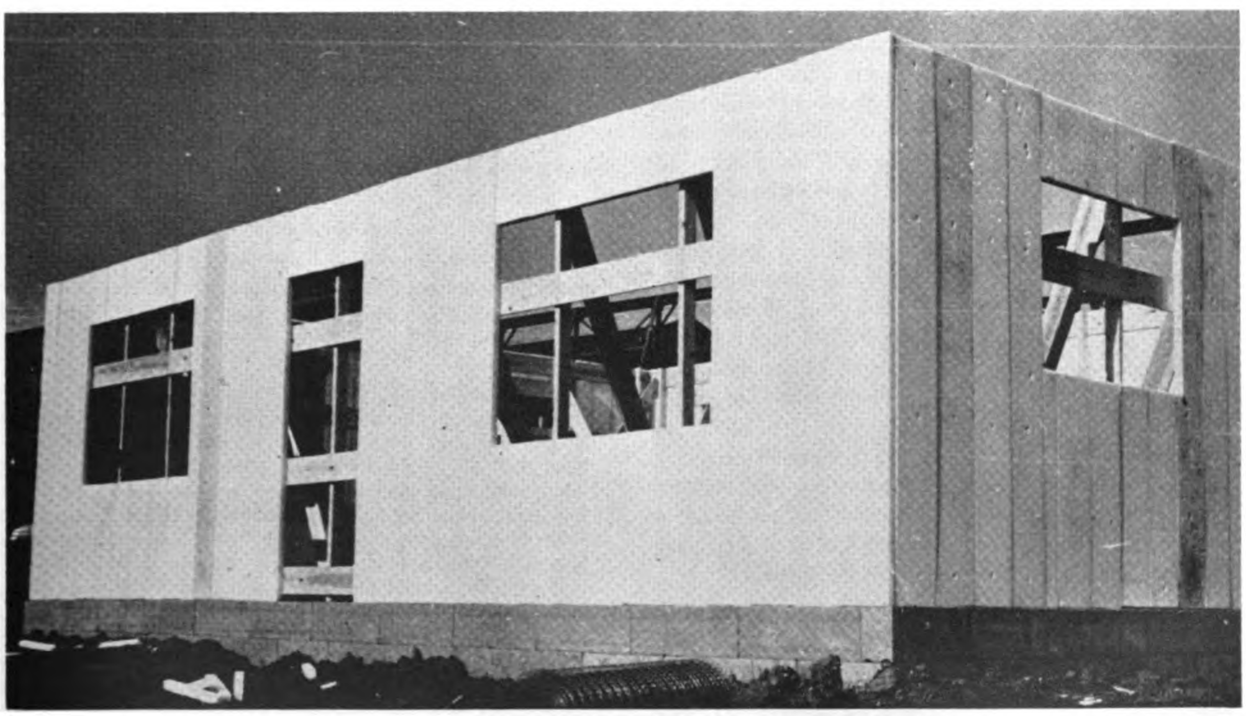

FIG. 2.2.8: Another expanded polystyrene board load-bearing wall

attention to this problem is necessary. The problems resulting from water in walls, roofs, floors and foundations are well-known—exterior point paint blistering, loss of insulation effectiveness, decay of wood, and unpleasant dampness on floors and in basements.

The primary function of a vapor seal is to prevent the passage of water and water vapor. In addition to having low water vapor transmission and being durable after installation, it must be puncture proof and tear resistant to allow economical installation without impairing the water sealing properties. Vapor seals are applied at the point in a structure where the water-partial vapor pressure averages the highest. Above grade, this is generally on the inside (warm side) of the building, while in foundations and floor slabs the seal is placed on the outside.

POLYETHYLENE AS VAPOR BARRIER

Several plastic films and plastic film—aluminum foil laminates have sufficiently low water-vapor transmission rates to classify them as water-vapor barriers. Most of these, however, have not been used in building construction because of cost, puncture resistance or lack of economical installation methods. Recently, because of the availability of low-cost polyethylene film, considerable work has been done on its use as a vapor barrier in walls, under floor slabs and in crawl places of dwellings.

Polyethylene film is a tough, water-resistant material available in widths up to 16 feet and in varying thicknesses. It does not deteriorate with age, become brittle or crack. It is unaffected by extreme temperatures or humidities.

As a vapor barrier, polyethylene film is used in thicknesses of 2, 4 and 6 mils. Walls and ceilings exposed to unheated areas are vapor-proofed with a two-mil thickness applied as near as possible to the warm side of the construction. Where joints occur, they are placed over solid or continuous backing and are laped from three to six inches. The joints may be heat-sealed to form a continuous barrier. In wood floors the polyethylene film is laid between the wearing floor and the subfloor.

Four- to six-mil film is recommended for concrete floors and foundation walls. It may be positioned against the outside wall before back filling, or it may be placed on the inside form before the foundation is poured. On concrete floors the film should be applied over a sub-grade which has been smoothed to eliminate protrusions that will cause damage or rupture the film.

The use of polyethylene film as a vapor-barrier material has been accepted by several Government agencies interested in housing developments.

The recently-introduced Mylar polyester film-aluminum foil laminate, which has extreme toughness and zero water-vapor transmission rate, should find application in the building field. Thus far, this material has been used primarily as a vapor barrier to protect insulation in low-temperature applications in which the water-vapor problems are much more severe than is the case in most buildings.

PLASTICS IN STRUCTURAL PANELS

By A. T. Waidelich*

The Austin Company

IN CURRENT technical literature, it is apparent that there is no generally accepted definition of building "panels." The term is used for everything from simple glazing and corrugated sheets to large, complex sandwich construction.

To avoid overlapping other papers at this conference, this paper will limit its discussion of "structural panels" to large prefabricated building units, made up of two or more components—which units, in addition to other functions, must carry certain live loads, either in the plane of the panel or transverse to it.

The use of such structural panels in buildings is a relatively new development—in any material; and only very recently have plastics been used in these panels. This paper describes a number of such installations.

Structural panels—again, in any material—can be produced most economically when there is a great deal of duplication. Two building fields, in particular, allow this degree of duplication: individual houses, and the field of larger buildings. Because of basic differences, these two fields of application will be considered separately.

STRUCTURAL PANELS FOR HOMES

The traditional frame house has a framework of vertical studs, with sheathing on the outside of the studs and some type of finished wall on the inside. Structural panels can be incorporated into this type of construction by using a more open framework of structural members on which, or between which, can be placed insulated panels. Essentially, this was the technique used in the Lustron porcelain enamel house which had a light steel framework. Plastic panels could be used with a similar framework, but this approach is not too attractive—there are too many elements and units, and a great deal of field labor.

If plastics are to be used economically in structural panels in houses, we will probably have to depart from this traditional construction and follow the lead of more recent prefabricated housing. In individual houses, the spans and the loads are so small that the walls can be structurally adequate without any skeletal framework.

Thus, it is possible to build the walls, partitions and roof of a house using only a relatively few prefabricated structural panels. Such panels have generally been conceived as a sandwich with thin, strong exterior faces separated by a thicker, but lightweight, core material.

The U. S. Forest Products Laboratory has made extensive tests[1] of this type of house construction on an experimental building at Madison, Wisconsin. The walls, floors, partitions and roof were prefabricated sandwich panels (Figure 2.2.9). Most of the panels had paper honeycomb cores, but several facing materials were used for comparative purposes: veneer, plywood and aluminum.

This experimental building was erected over seven years ago and, apparently, at that time plastic facings did not receive serious consideration; at least none was used. However, phenolic resins were used to impregnate the paper honeycombs and as a glue in the sandwiches.

About six years ago, the first Acorn House[2] was completed in Concord, Massachusetts. This also used sandwich panels of waterproof plywood on a paper honeycomb, but went a step further in having the panels hinged so that the house could be folded up to about one-fifth its volume, trucked to the site, and again unfolded into its finished form (Figures 2.2.10 and 2.2.11).

These examples are mentioned—not because they indicate the *only* approach to plastic structural panel in houses—but because they do seem to provide one approach that has potentialities for success.

In Midland, Michigan, several houses[3] have been built using 4 foot by 8 foot structural wall panels consisting of faces of ¼-inch waterproof plywood

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[1] U. S. Housing and Home Finance Agency, Technical Paper No. 7, February 1948.

[2] Architectural Record, May 1950.

[3] Designed by Architect Alden Dow.

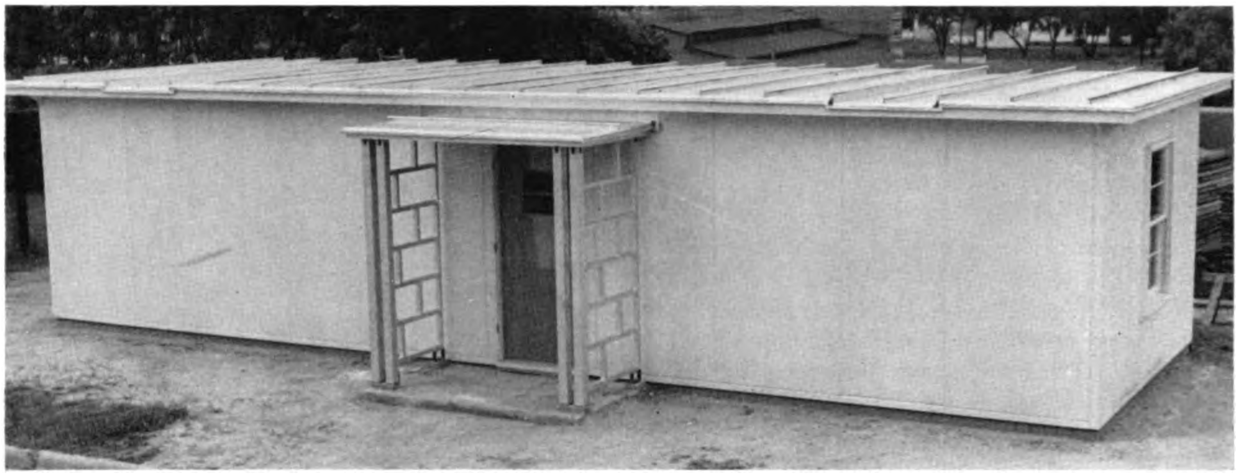


FIG. 2.2.9: Forest Products Laboratory experimental house

bonded to a core of expanded polystyrene. The adhesive also is a plastic—a recorcinol-type thermosetting resin. By the use of a press and dielectric heating, true flat panels were cured in about one minute.

In the first house using these panels, a vertical 2-by-4 wood spline was used to join the panels. In later houses, the splines also have been a sandwich and the spline and panels have been glued together in the field, using a portable dielectric heating unit (Figure 2.2.12).

The oldest of these houses has been occupied for several years and the performance of the panels has been reported to be entirely satisfactory.

The expanded plastic core ably carries out its functions: to stiffen the structural faces, to provide ample and continuous insulation, and to act as an excellent vapor seal. In addition, this core material is sufficiently compressible so that, when pressed between the plywood faces, it conforms tightly and uniformly, thus permitting a very satisfactory bonding of the three components.

Expanded polystyrene has also been used in over 150 houses at Port Huron, Michigan. There the structural wall panels are precast concrete slabs backed by a one-inch-thick board of the expanded plastic. The plastic insulation board is placed in the form and then the concrete is poured on the insulation. An intimate bond develops upon setting. The precast panels are then trucked to the site and erected. After erection, an interior plaster coat is applied directly to the expanded plastic.

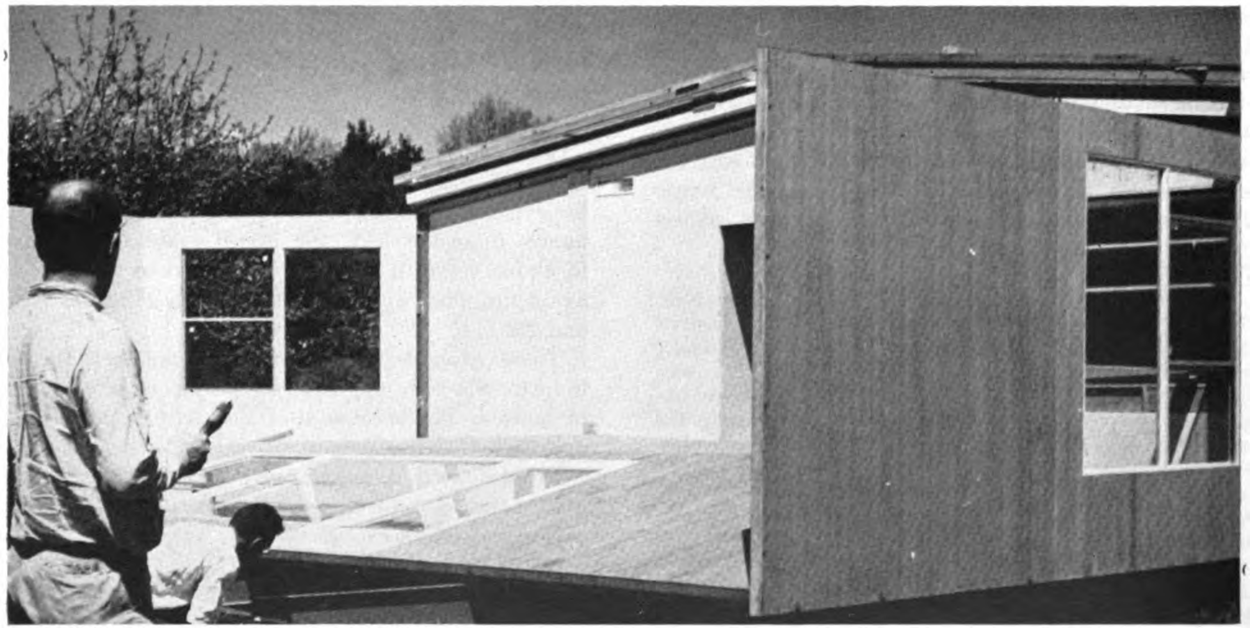


FIG. 2.2.10: Assembling sandwich panels for Acorn House

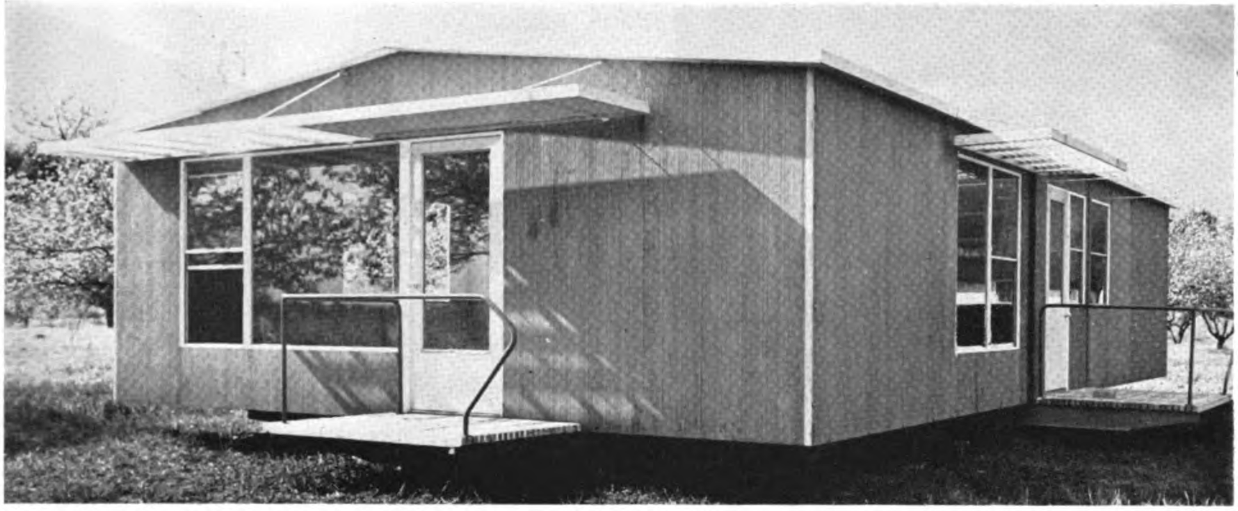


FIG. 2.2.11: Completed home by Acorn Houses, Inc. Concord, Mass.

ALL-PLASTIC PANELS

From these types of panels, there is only one step remaining to achieve an all-plastic structural panel—the use of stiff plastic sheets for the faces. These faces could be a single thickness of plastic, or a laminate. To best fulfill their different functions, the outside face could be of a different material from the inside face. Similar panels could be used for the partitions.

Such panels are now under development and will be described later, but to my knowledge there has been no house built using all-plastic structural panels. It may be some time before we will see such a development—as much for sales and promotional reasons as because of technical problems. In the meantime, however, there is no reason why plastics should not be used for one or more of the components, with plywood, metals or other materials making up the remainder of the sandwich.

How quickly plastics may replace some of these other materials will depend on ingenuity and on developments of both builders and chemists. For the builder, there still remain many problems in design and details, such as finding satisfactory methods of joining the panels and techniques for reducing the cost of fabrication and erection. For the chemist, there is the problem of reducing the cost of the plastic materials and, at the same time, improving their properties—particularly their ability to withstand higher temperatures. If self-extinguishing plastics could withstand the ignition temperature of wood, they would be better fire risk than wood, which is still the predominant material for house construction. Progress is being made in this direction; only about a month ago there was an announcement of a reinforced plastic laminate that will withstand temperatures of 500 degrees.

As contrasted with houses and other small buildings, larger buildings generally consist of a skeleton structural frame which is clothed with walls and a roof. If the building has more than one story, the floors above grade are also carried by the structural frame. And, in general, partitions and other interior walls carry no vertical loads other than their own weight.

At present, the use of plastics for the structural

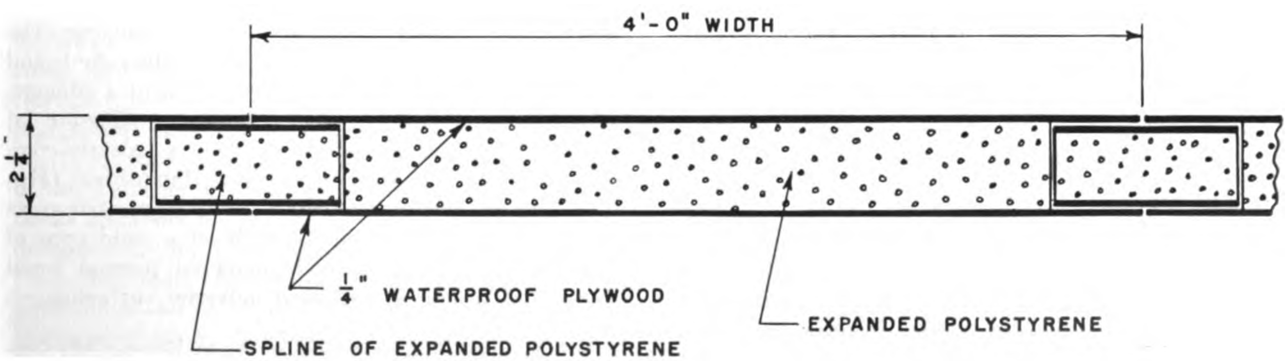


FIG. 2.2.12: Plywood-faced plastic structural panel

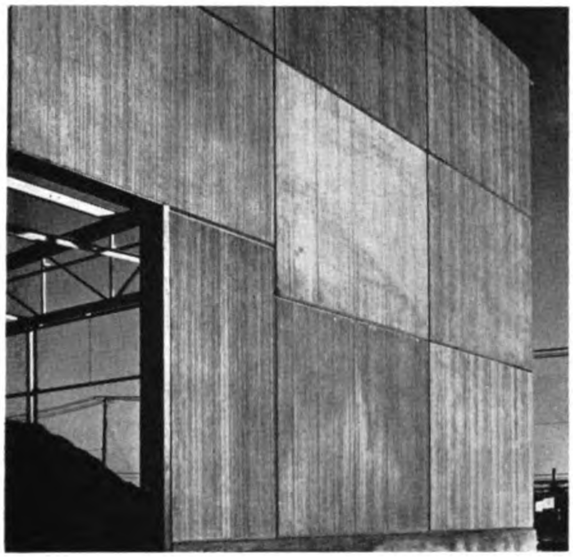


FIG. 2.2.13: Wall has an insulating core of expanded polystyrene.

FIG. 2.2.14: Decorative plastic structural paneling

frames of *large* buildings is not a live prospect. Plastics cannot compete in cost with steel or concrete for major structural members. But—even more basic—plastics do not yet have the necessary strength under higher temperatures. There is a possibility that plastics may be developed which will be sufficiently strong and resistant to high temperatures to be suitable for the structural frame. If they can also be made at a competitive cost, they might then be used for structural members. However, plastics do have an immediate field of application in the shell of the building, particularly in wall panels and in partitions. There are a number of examples of such applications.

PANELS HAVE PLASTIC CORE

A large warehouse building in Midland, Michigan, has exterior walls made of precast wall panels with an insulating core of 1½-inch-thick expanded polystyrene (Figure 2.2.13). The thickness of the concrete surfaces is 1¾ inches, making a total slab thickness of 5 inches.

These panels[4] are 8 foot by 10 foot and are supported by structural steel framing. The appearance of the wall is attractive and the performance has been satisfactory. As was mentioned earlier in discussing wall panels for houses, expanded plastics have numerous advantages as an insulating core material.

Plastics have also been used as the skins of sandwich panels with honeycomb cores. Three such panels were installed in the Radar Research Laboratory penthouse at M.I.T. They consist of 1½-inch-thick paper honeycombs impregnated with a phenolic resin, bonded between skins consisting of a clear polyester reinforced with glass cloth.[5] Two of these panels are 8 foot by 10 foot and are used in walls; the other panel is 8 foot by 12 foot and is used as a skylight. Plastics were used because they permit excellent transmission of radar signals, and the sandwich construction was used to develop adequate strength for wind (and snow) loads.

Since the penthouse is on the roof of a six-story building, these panels are exposed to substantial wind pressures. In fact, these panels successively survived the two hurricanes which hit Cambridge this fall with wind velocities of up to 100 miles per hour.

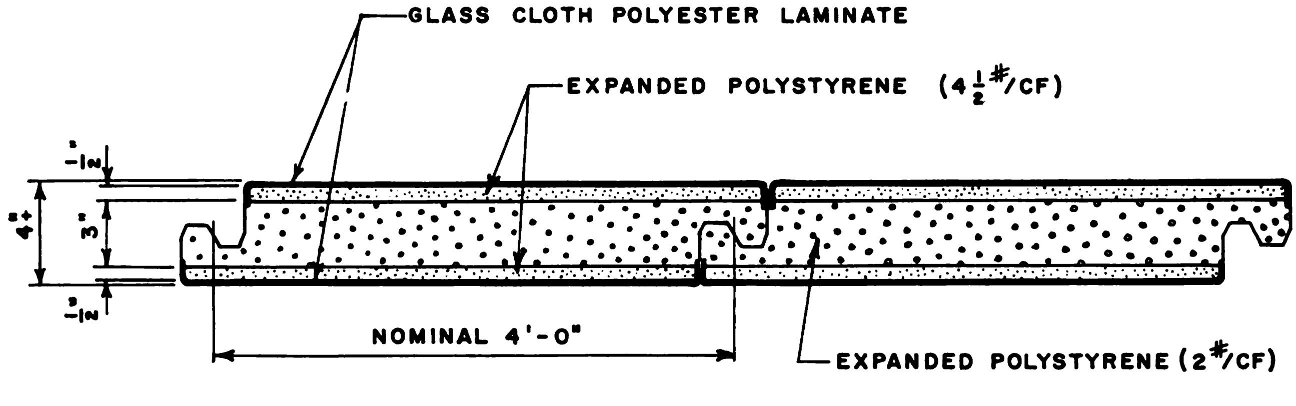
In our electronic civilization, plastics will have many structural applications in which it is important to avoid the distortion of radio signals. For some time, the Weather Bureau has used spherical plastic shelters for housing meteorological direction-finding equipment. These spheres are about 14 feet in diameter and are assembled from eight interlocking panels. Although these sections are each a single skin, they can be classified as structural panels since they have great resistance to lateral loads, both because of their shape and because they have radial flanges. The material is a laminate of 12 layers of glass cloth and a plastic resin, with a finish application of a silicone.

A most interesting variety in the application of plastics to structural panels occurs in a recently completed building at Manchester, New Hampshire[6] (Figure 2.2.14). One panel, between two large sash areas is three inches thick and is made of a solid core of balsa with skins of ⅛-inch tempered pressed wood board, on which is a sprayed polyester surfacing.

[4] Fabricated by The Marietta Concrete Corporation.

[5] These panels were fabricated by Acorn Houses, Inc., Concord, Massachusetts.

[6] Office and plant of Keller Products, Inc. The panels described were designed and fabricated by this company.



EPOXY RESIN ADHESIVE THROUGHOUT

FIG. 2.2.15: Composition of a plastic structural panel

There are also a number of similar panels which are 4 feet wide by 20 feet high. The exterior surface is sprayed with a pigmented polyester to achieve a rust color. The interior surface is a polyester-impregnated printed paper. The panels are joined in an extruded aluminum shape.

Ten light-colored wall panels are 4 feet wide by 10 feet high and have an aluminum grid as a core. Bonded to this core are skins of 0.050-inch thick polyester, reinforced with glass fiber mats. These panels are translucent and, with light on the opposite side, the rectangular pattern of the aluminum grid produces an interesting effect.

This building also contains four similar panels 4 feet by 16 feet which are installed in the roof as horizontal skylights. And, as a matter of interest, it should be mentioned that the floors of the second story are structural panels using a 4-inch-thick paper honeycomb and plywood skins. In these panels, plastics are used only for bonding and to impregnate the core.

IS AN EVOLUTIONARY APPROACH

This building is of particular interest because it indicates the evolutionary approach which has been taken with respect to both structural panels and the use of panels in them. Actually, the use of prefabricated structural panels of large dimension is itself relatively new—in any material. Many problems in design and in the basic details of the joints still are short of their ultimate solution. Therefore, many of the problems of using plastics in structural panels result from the shortcomings of the particular panel design—and not from the plastic.

In developing structural panels in the building field, much can be learned from the earlier experience in transportation. Sandwich panels have been used for some time in aircraft; are rapidly gaining favor in truck and trailer bodies, and have invaded the field of naval architecture.

Sandwich plastic panels were used in the superstructure of a 96-foot towboat completed early this year.[7] Its superstructure is really a small building; it has a structural framework of aluminum members which support the roof and the exterior and interior bulkheads, all of which consist of plastic structural panels. The largest panels (in the roof) are 9 feet 4 inches by 4 feet and are 1½ inches thick. All panels have faces and edges of polyester resin reinforced with glass fibers and are pigmented to achieve the desired color.

For test purposes, a variety of core materials was used: expanded vermiculite, end-grain balsa, impregnated paper honeycomb and cellular cellulose acetate.

About a month ago, another vessel was announced, of which practically the entire structure is plastic. This is a 50-foot, self-propelled inland waterway barge for the Army.[8] The hull consists of a number of sections—each a complete water-tight unit—which can be shipped individually and assembled in the water.

The outer skin of the hull is 3/16-inch thick and is a laminate of polyester resin reinforced with glass cloth. The inner skin is similar but only 1/8-inch thick. These skins are bonded to a 1-inch-thick, 8-ounce cotton duck honeycomb impregnated with phenolic acid. The resulting sandwich is reported to be more rigid than ⅜-inch steel and to weigh only one-fourth as much.

These hull sections were built up, in layers, over a plywood form, resulting in a seamless unit. Such a construction is not possible for a large building and

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[7] Designed and built by Nashville Bridge Co. and developed in cooperation with the Army Transportation Research and Development Command at Fort Eustis. The plastic panels were developed and built by Keller Products, Inc.

[8] Designed by W. R. Chance and Associates in cooperation with the Army Transportation Research and Development Command, and constructed by the Plastics Division of the Englander Company.

it is in working out the necessary joint details between the many wall panels of a building that a great number of the practical problems arise. However, the lesson that can be learned from this vessel is that it is perfectly practicable to make plastic structural panels that are just as strong and rigid as metals—and they will be much lighter in weight.

BRIGHT FUTURE IS FORESEEN

From the few examples given here, it is evident that plastics have good possibilities of satisfactory use as core material, as the sheeting on the core, and as surfacing on other sheeting material.

Probably this use of plastics—in conjunction with other materials—may prove to offer the plastics industry its largest market in structural panels. However, the possibility of satisfactory all-plastic building panels is also good.

There has been considerable development work on one type of all-plastic panel, which is now available in certain dimensions.[9] It consists, essentially, of expanded polystyrene, bonded between faces of glass cloth polyester laminates (Figure 2.2.15). The core material, the plastic bonding material and the reinforced faces are all self-distinguishing. For different applications, variations are possible in the density of the core and in the thickness of the faces.

While studying the place for plastics in building, its use as an *aid* to conventional construction must not be overlooked. One such interesting use for plastics is as a form for concrete construction. The strength and resilience of plastics, their smooth surface, and their resistance to water and to the chemical action of fresh concrete are all important advantages in their use as concrete forms. But they have another important advantage in their moldability to any desired shape. Forms with curved surfaces—particularly if the surfaces are curved in two directions—always involve considerable work if they are made in wood. Curves present no particular problem with plastics and may even be an advantage in giving the form greater strength.

[9] The all-plastic panel developed by Haskelite Manufacturing Company, Grand Rapids, Michigan.

Such plastic forms made of reinforced polyester have been used in waffle lift-slabs. Their dimensions are roughly 2 feet by 2 feet by 10 inches deep. Although strong enough to retain their shape during the pouring of concrete, their flexibility makes it easy to strip them from the finished work. They have proved very satisfactory and one construction company reports that, after 30 reuses, the forms are still satisfactory.

Plastic forms were also used to precast the reinforced concrete floor and roof panels for a building in Washington State.[10] The concrete panels were as large as 4½ feet by 20 feet. The top slab was 1¼-inches thick with longitudinal edge joists 8 to 10 inches deep braced with transverse ribs 4 feet on centers.

The form was a single sheet of plastic ⅛-inch thick, supported on wood ribs in a steel frame. Each form was fabricated in one day by a boat builder who is producing plastic hulls. The form was a five-ply laminate of glass fiber and a polyester resin.

This form was light in weight (which facilitated handling and stripping), gave good heat transfer (for rapid steam curing) and was easily cleaned. The plastic was not stained by the form oil and produced a smooth, clean concrete surface.

Although these forms have a high initial cost of about $5 per square foot, it is reported that they are virtually indestructible and that they are still serviceable after several hundred reuses. Any holes that may occur can be patched easily.

CONCLUSION

Thus, there is an intriguing two-fold future for the use of plastics in structural panels: as components of the panels themselves; and as forms for precast concrete elements. This latter use should not be overlooked while pursuing the more glamorous goal of an all-plastic building. The essence of the successful precasting of concrete is a strong, dimensionally-stable, easily-stripped, easily-maintained form that will permit hundreds of reuses. This construction market is available to plastics today.

[10] Engineering News-Record, October 22, 1953. The forms were designed and used by the Associated Sand and Gravel Co., Everett, Washington.

GENERAL DISCUSSION

MR. HUNTZICKER: We are going to call Mr. Kennedy and Mr. Waidelich back to the platform for a question period which will be moderated by Mr. Abner L. Roe. Mr. Roe is Vice President and Treasurer of the the Wm. P. Lipscomb Company, Inc., in Washington, D. C. He is a graduate of the College of Engineering and Architecture of the University of Michigan. He formerly worked for the James Baird Company, Inc., as Vice President of its Washington office, and with the United States Navy Civil Engineer Corps. He is currently President of the Master Builders Association (A.G.C.), a member of the Construction Contractors Council, Washington Board of Trade, Washington Kiwanis Club, and the Washington Building Congress. He is a member of the District of Columbia Commissioners' Building Code Committee.

I feel that Mr. Roe should be in a very good position to moderate a question period. Mr. Roe?

MR. ROE: With this introduction, I don't know exactly what to say; I don't know that I have ever been a moderator before, but I will try. I feel like the lad who walked into the antique shop and said, "What's new?"

I am sure we all found out a lot of things that are new. I don't want to take up time as a moderator to offer suggestions, but as a practical builder I would think that those of you here in that same classification would be thinking of cost, availability of material, what labor handles this new material, and whether we are going to get into any jurisdictional disputes over it—and various and sundry things of that kind. I am sure you have questions, and I don't have to offer suggestions as to what they might be.

I am advised by our staff here that your questions must be addressed to me. I will then repeat them over the microphone so that everybody will hear. I think we have about twenty minutes. If anyone has any questions? . . .

MR. KERN (Kern Modernizers): Mr. Waidelich showed a slide on an expanded polystyrene floor which had been affixed by polyester resins. How did he solve the problem of not allowing polyethylene lining in contact with polyethylene foam?

MR. ROE: The question was in reference to the make-up of one of the structural panels that was shown on a slide. Mr. Waidelich?

MR. WAIDELICH: Actually, the skin was polyester, but the bonding agent was not. My notes say it was epoxy.

MR. A. M. STOVER (Naugatuck Chemical Company): I'd like to ask Mr. Kennedy if there is any problem in expansion and contraction of polystyrene foams when used as insulation, such as in temperature changes.

MR. KENNEDY: Yes, there is a problem that must be considered in the expanded form, and the thermal coefficient of expansion is very much like that of the basic plastic which Professor Dietz showed you this morning. This can generally be overcome by use of adhesives in the bonding agent. The expanding of polystyrene foam particularly is less than that of its elongation, I will say. So, if you bond it with Portland cement mortar or plaster, there is no problem resulting from expansion and contraction due to changes in temperature. In other words, the expansion can be restricted by faces. In the case of these panels, if there were any difference between the faces and the core material, it would be taken care of by the adhesion between the base and the core.

MR. S. C. NILO (Rome, N. Y., Air Development Center): Mr. Kennedy, you pointed out a disadvantage for the alkyd-isocyanate expanded form would be a matter concerning the handling and installation. In the case of three feet maximum, perhaps four feet maximum, prefabricated panel construction, wouldn't the "foamed-in-place" resin be advantageous because, in the case of certain skins at least, it is capable of adhering to them inherently?

MR. KENNEDY: I think I can briefly answer that question by saying: yes, it is. It would be an advantage in prefabricated panels. I generally weighted these as if they were to be used on the job—like wall insulation on buildings that were already erected, or roof insulation, perimeter insulation, and the like. Expanded material could be used—will be used for prefabricated panels.

MR. ROE: Our former speaker referred to Hurricane Hazel and what she did with plastics. I am inclined to think this whole industry is tied up with panels.

MR. HIRAM McCANN (MODERN PLASTICS magazine): In making the prefabricated panel, using a completely cured polystyrene foam with a glass polyester skin, do you find any leaching of the polyester skin from the structures of the polystyrene foam?

MR. ROE: I hope you heard that, Mr. Kennedy.

MR. KENNEDY: I will say this: that the development is relatively new, but if the polyester skin is secured properly, I don't think there will be any leaching. Certainly the panels have been exposed now for several months, and I know that during the summer there was no evidence of any leaching, any parting of the bond. But I don't believe there would be any leaching. Perhaps if you would have, for some reason, a skin that wasn't completely cured, you might have not only leaching . . .

MR. McCANN: I am talking about in the course of the cure.

MR. KENNEDY: Now, with regard to these panels Mr. Waidelich spoke of—the skin was pre-cured and then adhered to the foam by epoxy adhesive.

MR. McCANN: And you wouldn't suggest making one the other way?

MR. KENNEDY: No. The polyester resin attacks polystyrene foam.

MR. ROE: Does that answer your question?

MR. McCANN. Yes, sir.

MR. R. A. MANSFIELD (B. F. Goodrich Company): My question is directed to Mr. Kennedy. On the chart you had polystyrene rated excellent for handling and insulation. In the case of the polyvinyl chloride and urea-formaldehyde, the rating was unsatisfactory. What is the reason for the difference between those products with regard to handling and insulation?

MR. KENNEDY: I think I can easily answer the question with regard to the urea-formaldehyde. The urea-formaldehyde is very weak in form. I don't think you could pick up a piece of any size at one end without having it break off. My information is a little weak on the polyvinyl chloride. There, I was considering the expansion in place. I don't know whether present techniques permit making large pieces that would be handled on the job. I believe that the only materials that are rigid are also fairly high in density—at least above four, five or six pounds per cubic foot—which would make them difficult to handle.

W. BURDETTE WILKINS (Consulting Engineer): I'd like to ask Mr. Kennedy what pounds-per-square-inch pressure is used in laminating those panels?

MR. KENNEDY: What panels are you referring to—the polyester skin?

MR. WILKINS: Polystyrene foam.

MR. KENNEDY: I am not sure of the exact pressure. Just contact pressure—enough pressure so that the skins are held against it as would be necessary for bonding adhesive, for getting bond. I would guess that is under 10 pounds to the square inch.

MR. ROE: All these questions are so highly scientific and over my head that, just to be different, I am going to ask a simple question of Mr. Waidelich. How does the cost of this polystyrene insulation compare, for instance, with the cost of cork or fiberglass or one of the other insulating materials that we use in roof construction?

MR. WAIDELICH: That's a simple question? (Laughter.) That's not my idea of a simple question at all. You may notice I have very carefully avoided any question of cost of these panels. The reason is that there have been so few of them built that I don't think any cost figures (of any that have been built today) mean anything. In other words, if you build 10 panels 4 feet by 10 feet in dimension, you certainly haven't got any basis for saying what the cost for panels of that type will be when you are really using them in construction work. I look at it as practical experimentation in which we are trying out techniques and developing details. I think every one that's been built to date probably costs far more than conventional construction. I wouldn't know what the future cost is going to be.

MR. ROE: Still in the experimental stage on most of these?

MR. WAIDELICH: As far as I am concerned, that's true. Originally—well, as someone said, it practically has no past. It has a big future.

MR. ALBERT L. LLOYD (Public Housing Administration): I would like to ask Mr. Kennedy a question on polyethylene film as a vapor barrier under the concrete slab. What assurance can you give us that this vapor barrier under the concrete slab will last for a period of time equal to the life of the bonds which pay for it—say, 40 years?

MR. ROE: That's a good question, Mr. Kennedy.

MR. KENNEDY: Well, you are asking a question very similar to those of this morning regarding length of life of materials and the effects of weathering. I can only say that, since there isn't a past history, we can only go by what we know about other types of plastics; how long they have lasted, things that affect plastics, how they are destroyed. We also gain some information by the use of accelerated tests.

MR. ROE: Does that answer your question? I am sure it doesn't, but that's the best we can do. Nor do I think anyone else has the answer to this.

MR. KENNEDY: We can't answer for 40 years. Forty years from now we can say: "It's been used for 40 years."

MR. ROE: I have another question that goes along with the last question asked by the gentleman out here. It's about the use of this polyethylene that you used on wall construction for vapor seals in 16-foot width. What job aplication do you use to seal the edges? Do you use blow torch, or what?

MR. KENNEDY: I didn't say I am as familiar with the vapor sealing foams as I am with plastics. I believe they can be sealed with an adhesive. I think use of a heat-sealing device is generally preferred. I know that, in the making of bags from polyethylene, they use a jaw type of heat sealers. I would imagine that, for the use in building, you could construct a roller type of heat sealer which would be run along, sealing the two edges together. Maybe there is somebody in the audience who can answer that much better that I can.

VOICE FROM THE AUDIENCE: Flatiron.

MR. ROE: A flatiron will do it? At what temperature? (Laughter.) Having no answer to that question, are there any other questions?

MR. JOHN J. REED (Allied Chemical & Dye Corporation): What resistance—if there has been any—on the part of workmen has Mr. Waidelich experienced in the use of plastics in construction?

MR. WAIDELICH: I don't believe I know of any example of resistance by workmen to the use of plastics. I don't know why they would object to it. Of course, there is the old story again: we haven't used it in large enough quantities to create much of a jurisdictional dispute. But we do know that, with some of the other wall panels, in erecting large buildings there have been quite long discussions about how the trades were to divide up the work. I can foresee that, as plastic structural panels become used a great deal, there are bound to be jurisdictional disputes on which trades will erect them. However, up to the present time I don't think there has been any difficulty.

MR. ROE: I wish we could continue, but I am told we are running on a very tight schedule. I want to thank you for your attention and your questions, and I hope that this session and these papers have been instructive and helpful to you. Thank you, Mr. Kennedy and Mr. Waidelich. (Applause.)

SURFACING AND DECORATIVE USES OF PLASTICS IN BUILDING

By Hiram McCann*

Editor, *Modern Plastics*

I AM going to talk about decorative and durable surfacing plastics materials for floors, walls, and built-in work surfaces. Because of time limitations and for simplification, I have arbitrarily limited the subject to vinyl flooring, thermoset decorative laminates, and styrene wall tile. Basically, I am going to present a catalogue of product comparison, as simply as I can.

VINYL FLOORING

Let's start with vinyl flooring. The first vinyl floor ever laid was manufactured by Johns-Manville in 1933 for The Bakelite Company's booth at the Chicago World's Fair. I belive it was a composite of vinyl chloride and vinyl acetate copolymer resins with asbestos and other fillers. At the Fair it was tramped on by almost 20,000,000 people; after the Fair was closed, it was removed and reinstalled in a high-traffic area at the Boundbrook, New Jersey, Bakelite Laboratory. Today, 20 years later, that tile is almost as good as new.

Vinyl floor coverings when produced in conformity with Interim Federal Specification L-T-751 are superior to other non-vinyl floor coverings in resistance to grease, alkalies, strong cleaners and many household reagents. They also have excellent retention of flexibility and pliability on aging and are characterized by extreme color clarity and brightness.

So many different kinds of vinyl flooring are now marketed that you, as architects and builders, are faced with the need to make a number of decisions in specifying it. First, is it to be used above grade, on grade, or below grade—on wood or on concrete? Second, is it to be used over floor radiant heating? Third, is it to stand up to dropped cigarettes? Fourth, must it exhibit a fast return from heavy static indentation (for example, filing cabinets or business machines) or from temporary indentations like casters and wheels and the feet of tables and chairs? You need not worry about grease and most common household chemicals.

Out of some 18 manufacturers of vinyl flooring materials, I received survey replies from 14 and I shall tell you briefly what each has to offer.

In general, there are four basic types of resilient vinyl floor coverings on the market today: flexible homogeneous; semiflexible vinyl asbestos; laminated vinyl wear layer, and clear vinyl wear layer over a printed pattern. The flexible homogeneous type is usually 1/8-inch thick and is a composite material throughout its whole thickness with a 100 per cent wearing factor. It resembles rubber tile to some degree. The semiflexible vinyl flooring is also composite in structure throughout, usually contains more asbestos fiber than the flexible type and has a 100 per cent wearing thickness. The laminated vinyl wear layer type is available in roll and tile form and has a 20 to 50 per cent wearing factor, the vinyl wear layer being 0.020 to 0.035 inch thick on a backing of impregnated felt or other material. The clear vinyl wear layer type has a film of transparent vinyl bonded securely to an impregnated felt base on the surface of which is a pattern or design, usually applied by the gravure printing process. The pattern is protected from wear by the clear vinyl film.

The flexible and semiflexible types generally require special adhesive application and laying on or below grade. The film laminate type is probably more suitable for the do-it-yourself market.

In the interests of fairness, I am referring alphabetically to vinyl flooring and its makers.

1. The Armstrong Cork Company, Lancaster, Pennsylvania, with seven versions of "Corlon" Vinyl flooring, five of them laminates, one a semirigid tile composite, and one a rigid vinyl plastic asbestos tile. The five laminate versions are available in roll goods, and are recommended only for installation on suspended floors. The semirigid vinyl-asbestos tiles are recommended on any type of subfloor including below grade where the concrete is in direct contact with the ground—provided Armstrong's recommended ad-

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hesives are used. The vinyl plastic tiles are recommended for both suspended and on-grade subfloors.

2. Congoleum-Nairn, Inc., Kearny, New Jersey, with a laminate in roll and tile form, and a semiflexible vinyl asbestos tile.

The laminate is a copolymer of vinyl chloride and is known as Gold Seal VinylFlor, VinylTile, or VinylTop. This product is remarkably versatile as to use. Either in roll or tile form, it may be used as a floor covering on suspended wood or on concrete underfloors. The tile may also be installed over on-grade concrete (with or without radiant heating), using special adhesives recommended by the manufacturer. Gold Seal VinylTile is made in special decorative effects particularly suitable for wall installations. Gold Seal VinylTop is used as a resilient covering for work surfaces, such as sink and counter tops, where its flexibility permits easy coving and installations with minimum joints and seams.

Congoleum-Nairn's semiflexible tile, Gold Seal VinylBest, is recommended for installation on any type of subflooring, using special adhesives recommended by the manufacturer in the case of installations over concrete which is on or below grade level or which contains radiant heat.

3. Conneaut Rubber and Plastic Company, Conneaut, Ohio, which is the Floor Division of U.S. Stonewear Company manufactures a product called "Plastile," is a semirigid tile flooring ⅛-inch thick with extremely high abrasion resistance. It may be laid below grade providing the concrete surface is membraned.

4. Dodge Cork Company, Lancaster, Pennsylvania, produces, on a cork base, a range of vinyl-cork tile with either transparent or opaque pigmented vinyl over the cork. It is said to have all the advantages of cork flooring, to have certain thermal insulation properties—which is natural—and to have many of the advantages of vinyl floors. Since it is extremely flexible, it may be used for covering and wall surfaces as well.

5. Tile-Tex Division of The Flintkote Company, Chicago Heights, Illinois, commercially introduced, in 1938, a vinyl plastic-asbestos floor tile known as flexachrome. It is produced in 1/16, 3/32, and ⅛-inch thicknesses. Flexachrome combines the advantages of all types of resilient flooring tile and it can be installed on any sound, smooth subfloor.

6. The Floring Division of The B. F. Goodrich Company, Watertown, Massachusetts, offers Koroseal tile, a semi-flexible type in .080 and ⅛-inch thicknesses. This product is a composite of asbestos, vinyl copolymers, plasticizers and stabilizers. It may be installed above or below grade with recommended adhesives, using normal installation procedures.

7. The Goodyear Tile and Rubber Company offers residential All-Vinyl flooring and H.D.H. (heavy-duty homogeneous) All-Vinyl flooring by the roll and as completely flexible ⅛-inch-thick vinyl tile. Special requirements are specified for the use of these materials over low radiant heating and below grade.

8. The Johns-Manville Corporation, New York, which manufactured the first vinyl floor ever made, offers Terraflex, a semiflexible vinyl-asbestos tile for general use, and also offers a range of decorative flooring tile inserts made from the same material.

9. Kentile, Inc., Brooklyn, New York, produces Kenflor laminated vinyl tile and Kenflex semiflexible vinyl-asbestos tile. Kenflor is not recommended for below-grade installation, but Kenflex, used with an emulsion-type adhesive, may be used on or below grade. Kenflex is widely promoted for the do-it-yourself market.

10. Aristoflex vinyl tile, is produced by the Mastic Tile Corporation, Newburgh, New York. It is a semiflexible material in 1/16-inch and ⅛-inch thicknesses, and may be applied anywhere with the use of recommended adhesives and techniques. A special feature of this tile is its claimed resistance to indentation.

11. Pabco Products, San Francisco, produces Floron tile, a low-cost combination of the flexible tile and the laminate. As with other laminate floorings, this is recommended in the do-it-yourself field.

12. The Sloane-Delaware Division of Congoleum-Nairn, Inc., makes four types of vinyl plastic floor coverings, two being laminates, one a semiflexible vinyl asbestos tile, and one a flexible homogeneous vinyl tile.

Flor-Ever Standard, is a copolymer of vinyl chloride and is available in both roll and tile form. It is a laminate and may be used as a floor covering over suspended wood or concrete underfloors. The tile may also be installed over on-grade concrete, with or without radiant heating, using special adhesives recommended by the manufacturer. In roll form, Flor-Ever Standard is used as a resilient covering for working surfaces where its flexibility permits easy coving and installation with minimum joints and seams.

Flor-Ever Vinyl Asbestos Tile is semiflexible and is recommended for installation over any type of subfloor, using special adhesives recommended by the manufacturer where the concrete is on or below grade or contains radiant heat.

Flor-Ever Universal Tile, a copolymer of vinyl chloride, is a flexible, homogeneous tile recommended for installation over the same subfloors and under the same conditions as Flor-Ever Standard Tile. In addition, to the standard tile form, Flor-Ever Universal comes in cove base, cove molding, cap strip, feature strip and wall corner strip.

Floran Vinyl-Plated Floor Covering and Counter Top is a flexible laminated vinyl film suitable for floor and working surface installation. For floor installations, Floran, which comes in roll form, may be laid without adhesives.

The two remaining makers who replied to my questionnaire have each a specialty worth studying.

13. The Robbins Floor Products Co., Inc., makes a flexible 100 per cent wearing factor tile, with a specially constructed tile for nonadhesive laying, and with a new tile for the do-it-yourself market with adhesive already on the back, protected in transportation and storage by polyethylene film.

Robbins manufactures probably the widest range of vinyl flooring materials in the market, has a runner material, and roll material, as well as the standard cove strips and feature strips made by all. The Robbins all-purpose tile is ¼-inch thick with pattern indentation on the back. It is laid with no adhesives and, if installed over an underlay of aluminum foil, creates a complete absorption field which dissipates static electricity. It is therefore important in hospital use.

14. The Sandura Company, Inc., Philadelphia, makes vinyl Sandran, a strong film laminate suitable for floor, wall and work surface application. For floor application this material, which comes in roll form, may be laid with no adhesive, although it may also be put down with standard linoleum paste. For wall and work surface application standard linoleum paste is also used, with waterproof adhesives recommended for critical areas around sink frames and water pipes.

There are a number of other makers of vinyl flooring materials on the market, but this presentation has been limited to those who answered our correspondence. For all these materials a few things may be said:

1. They are all made to standards in accordance with Federal Government specifications.
2. They are all chemically resistant, grease resistant and fire retardent.
3. The makers have millions of dollars invested in them and will go to any lengths in cooperation with builders and architects to insure satisfactory installation and service.

The sale of vinyl resin for use in flooring doubled in 1953 over 1952 and will probably have doubled again in 1954.

DECORATIVE THERMOSET LAMINATES

Our next subject is decorative thermoset laminates. These fall into the categories: (a) the melamine-surfaced phenolic paper laminate which comes in sheets, and (b) the polyester paper laminate which is available in continuous lengths.

Under the trade names, Formica, Panelite, Textilite, Micarta, Parkwood, Consoweld, Farlite, Decar, Nevamar, Richwood, and others, architects and builders know the melamine-surfaced high-pressure decorative laminates as the finest products ever produced by the plastics industry. They have the toughness to endure for years, have excellent resistance to abrasion, heat, mild acids and alkalis, water, oil, and solvents. They can be produced in an unlimited range of patterns and colors (including wood grain), and properly made, there is no chance of loss or degradation of color. They are light in weight and easily worked with carpenter's tools.

A slow but very important revolution has been going on over the past two years in the creation and application of the high-pressure decorative laminates. In the first place, the development of pressure-sensitive adhesives has made possible the application of the materials *on the job* rather than in woodworking shops. In the second place, the development of thicker laminates, wherein the material is used to surface a special grade of hardboard, has opened up tremendous possibilities for wall applications. Until recently, wall applications have been made by laminating to plywood and using the combination as paneling with the use of wood, plastic, or aluminum splines. Indeed, two makers are providing extruded aluminum splines covered with the same decoration as is on the laminate.

With this development it is quite likely that kitchen and bathroom interiors can be built without plaster by placing the metal splines in position and snapping the thicker laminate into the grooves right on the studs. Another possibility for wall application rests in the fact that these materials may now, with new adhesives, be applied to steel and aluminum sheet.

Doors surfaced with high-pressure melamine decorative laminates have always been very expensive, but again new adhesives and new techniques make it quite likely that paper honeycomb or foam core doors may be built to sell at reasonable prices in the near future.

Two of the laminators who wrote me believe that the NEMA quality standards for these materials are too high for wall surfacing requirements. Possibly a separate standard could be established for wall surfacing material which would enable the laminators to lower the price.

Architectural applications of this laminate are almost too numerous to mention. I am sure everyone in our audience is well aware of them. For example, Formica window sills, installed in the Statler Hotel in Washington over a decade ago, are still as good as new. About the only limitation to the future of these materials is that they are not yet suitable for outdoor exposure. Many companies are working on this problem and there is a strong possibility that the use of metallic pigments and new types of resins may give these laminates weather resistance.

The other form of laminate—the polyester surfaced paper—is lower in cost than the melamine high-pressure sheet, and can be had from some makers in continuous lengths.

Naugatop, made by the Mishawaka Division of U.S. Rubber Company, comes to the builder or user with the adhesive already on the back and by activating the adhesive with a solvent the material may be laid by even a rank amateur. Conolite, manufactured by Continental Can Company, has its adhesive separately packaged for brush and roller application. Lamidall made by Woodall Industries, Inc., Skoski, Illinois, differs from other polyester type laminates in that it is available in sheets laminated in the plant to a 1/8-inch tempered Presdwood base. This gives it a considerable advantage in vertical, or wall, applications. And Woodall Industries have made for them by Keller Products, Manchester, New Hampshire, a complete line of aluminum splines and feature strips matched to the laminate color and pattern.

POLYSTYRENE WALL TILE

The third section of this presentation is concerned with styrene or polystyrene wall tile.

In 1953 over $85 million worth of this product was sold, over 70 per cent of that to the do-it-yourself market. In the current year (1954) sales should quite comfortably pass the $100 million mark—tile plus adhesive.

The Society of the Plastics Industry, Inc., was instrumental, three years ago, in establishing a Federal Standard of Quality for styrene wall tile and today practically all manufacturers adhere to the standard. Normal tiles are 4¼ inches square. King size tiles are 4 times that or 8½ inches square. In between is an 8½-by-4¼-inch size. A component of each line of styrene wall tile is a full range of caps, corners, base elements, stripes, and butterflies.

I must single out with special mention, because of their cooperation with me, Franklin Plastics, Inc., Franklin, Pennsylvania, who make Cameo styrene tile in pillow, panel, and shadow form, to produce unique decorative effects; C. F. Church Manufacturing Company, Holyoke, Massachusetts; Hachmeister, Inc., Pittsburgh; Meridiam Plastics, Inc., Cambridge, Ohio; Detroit Plastic Molding Company, Detroit; Lincoln Plastics, Inc., Circleville, Ohio; S & W Molding Company, Columbus, Ohio; and Al Plastic Molders, Inc., Chicago. Also, Nalle Plastics, Inc., Austin, Texas who make ribbed or striated tile.

As most of this audience is well aware, styrene wall tile is completely acceptable for professional installation under F.H.A. codes. If properly installed with standard mastics and maintained without the use of abrasive cleaning materials, it is a most satisfactory wall surfacing material for both bathrooms and kitchens. Its limitations are poor heat resistance and lack of resistance to hydrocarbons—but in very few cases are circumstances involving these limitations encountered.

I would like to urge architects and builders to assist in getting styrene wall tile made to National Bureau of Standard specifications.

DECORATIVE ELEMENTS

You will note that I am not including vinyl coated paper or fabric surfacing materials in this presentation. The field is so broad that days would be required merely to outline the range of materials available. However, I think two decorative elements should be included:

One is the rigid vinyl copolymer sheet material created by Pan Laminates in New York and widely used today in commercial wall surfacing. This material is produced by putting cloth, burlap, fibrous glass, and even feathers between two sheets of transparent rigid vinyl copolymer to produce a material which, with transparent adhesives, may provide a permanent surface of walls.

The other important development—and one about which you will hear much more about from now on—is Plasti-Sprayed vinyl made by Progressive Industries, Inc., in Long Island City. It was used to cover 39 huge interior columns in the United Nations General Assembly building lobby. There are 37 10-foot columns and two 44-foot columns involved, with a total of over 5,000 square feet. They were spray coated with the equivalent of a vinyl sheet in just 10 days at a cost of 45 cents a square foot, and they have stood up perfectly under heavy public exposure.

CONCLUSION

In conclusion, the future holds remarkable developments in plastics surfacings. We are going to find a way to cast a floor out of sawdust or wood chips or broken rock mixed with a plastic casting resin. We are going to find a way to make composite structural materials, composed of a foam of honeycomb cores with plastics skins, which will be load-bearing elements of great structural importance. The revolution in adhesives will continue to provide us with new, faster and easier means of using plastics decorating surfacing for the protection of structures. The exterior laminate is just around the corner. A man in this audience, whose confidence I must respect, soon will be broadly marketing a new concrete block—surfaced with plastics. Thank you.

GENERAL DISCUSSION

MR. HUNTZICKER: The next part of this program is a chance to ask questions of Mr. McCann; a question period which will be moderated by Miss Ann Hatfield. Miss Hatfield is a partner of Ann Hatfield Associates in New York, and is an interior designer. She was formerly associated with Harrison & Abramovitz and is a graduate of Mount Holyoke and studied in Munich. She is a member of the American Institute of Decorators. It is a pleasure to have Miss Hatfield on this panel. Miss Hatfield, will you take over, please?

MISS HATFIELD: Mr. McCann has treated brilliantly, although rapidly, a fairly complicated and fairly rich phase of the plastics industry. It is also close to our hearts, as householders. It is appropriate, it seems to me, to start the questions immediately, particularly since I have a feeling that Mr. McCann has more to say and that his answers may bring it out. Yes?

MISS GRAYBOFF: I don't know if this is a question Mr. McCann should answer, or whether the chemists attending the conference should answer it. Would it be possible to have a vinyl resin packaged in a can (I don't necessarily mean for the do-it-yourself market, but for the professionals) and pack it with some kind of catalyst so it could be troweled on as a wall-to-wall floor?

MR. McCANN: There are people who can answer this better than I. We already have it. We have plastisol for pools. To give an example, I built my own ornamental pool. I can't afford an under-water light, so I put in a piece of plastic an ordinary basement-type lamp, and then I gasketed the thing with a plastisol resin which I painted on and then sealed with a blow torch. It just hasn't a market. When it comes to the point where those materials are necessary in the range of the packaging industry, it might be.

MR. GUY G. ROTHENSTEIN (Architectural Consultant): I want to ask why do plastics imitate other materials? I would also like to kind of comment on it myself. It seems to me the plastics industry is now developed enough to bring out plastics which look like plastics. I feel that maybe in 10 or 15 years we may have other materials more advanced, and I am wondering if they will imitate the looks of plastics. I'd like to hear what some of the people connected with the large companies have to say about the subject, because they are most responsible for the attractiveness of the imitation, which I object to.

MISS HATFIELD: Did everyone hear that?

AUDIENCE: No.

MISS HATFIELD: It is something I am glad to repeat: Why must plastics imitate other materials, such as cloth, rubber tile, and so on? Does anybody know whether or not it is a good thing?

MR. McCANN: I think there are two answers to that question. Of course, the gentleman who asked the question wants something entirely different, anyway. Number one, a great deal of the development of plastics came during the war. At that time a word became popular in use and this word has been used today, and I wish nobody would use it. I will whisper it once—*substitutes*. Plastics aren't. Plastics succeed and supercede other materials today. They are not substitutes for other materials. But, during the war when we were building an industry under the shortage of other materials, plastics were used to copy the materials.

MISS HATFIELD: There is sort of a special future for the appearance of plastics, probably?

MR. McCANN: Yes.

MR. JACK WOLFORD (Koppers Company, Inc.): I want to take comment on that last statement. I don't know that I can add much to what you say, but this is my experience: A number of years ago I perpetrated an invention on the unsuspecting public which didn't look like the thing it took the place of. It did do a better job, and was cheaper. But, it wasn't until I made it to look like what the public had been using that it was a commercial success.

MR. McCANN: Thank you, Jack. There are a number of people in this room old enough to remember the first automobiles most of which had whip stocks on them and dashboards. It's the same pattern over and over again, in changing times.

Another thing that is cogent to this problem, Madam Chairman, is the fact that your traditional labor crafts force a definite limitation upon you when you are using a new material. There is no law in the world that says polystyrene tile has to be the same size as a ceramic tyle, but they are used to that. A great section of the conservative public wants it and will not use a new material unless it comes in the same shape and form as the old one. Those who install tiles are used to that.

I built a new house about three years ago, and I had to lay one of the vinyl floors in that house myself, because the craftsmen hired by the builder didn't know about it and wouldn't touch it. Perfect example!

MISS MARION GOUGH (House Beautiful Magazine): I just want to ask Mr. McCann—perhaps he can't answer this question—if he knows, or can give us some idea, to what extent the plastics industry itself has gone toward having designers help them with their products. Or, do they just depend on their own good judgment of what the public wants? (Applause.)

MR. McCANN: We can take this from three angles. Number one: Take the case of the high-pressure laminates. Each and every one of those companies has on its retainer, or staff, a color and design expert who is well aware of the changing of trends in home decorating. Number two: Vinyl floor people—they are all big companies in linoleum and rubber and other types of flooring—are applying to these floorings the same decorative and designing talents. In the case of styrene wall tile, most makers are not multi-million-dollar corporations, but they have been put to a great deal of expense and trouble to get proper color selection. Does that partly answer it?

MISS GOUGH: Yes.

MR. KENNETH FRAZIER (Detroit Steel Products Company): Along with the first previous question, I am just interested to know, do you consider those sizes of tile as being modular? If not, what consideration has been given to modular sizes of tile?

MR. McCANN: Since early in Maurice Ketchum's career—and many of you knew him in smoke-filled rooms and conferences—this matter of module has come up. I don't know the answer. I don't know whether this is a proper module. It's just traditional, that's all, as far as I know.

MR. DAVID RUBENSTEIN (Chem-Stress Structures Company): I would like to state that for a long period, research and development have been carried out on concrete and plastics, and we are not yet at the place where all things are proven to our satisfaction. Of course, some are. But, wherever concrete is used as a product today, you can use plastics in some form or another as a part of, or adjunct to, the concrete.

MISS HATFIELD: Mr. McCann suggested that I bring the audience around to ask about maintenance. He thought there might be some questions on that, and we have a few minutes more.

MR. HENRY E. VOEGELI (American Brass Company): Has Mr. McCann any idea of a plastic film that would protect metals such as bronze, that is protect their color?

MR. McCANN: Bridgeport Brass is doing quite well right now, for a price. I don't know how permanent the material is. It's an acrylic. I don't know, I don't believe we have even—it's a bad word—scratched the surface of coatings. I think your plastics are going to be very firm in that direction. They cost money today, however.

MISS HATFIELD: One more question?

MR. JAMES L. CONKLIN (PLASTICS TECHNOLOGY): I am wondering why Mr. McCann admitted, probably unintentionally, in covering the subject of plastic coating an impregnated wall with a cloth covering, that there is probably more square footage of that sold for interior decoration than any of the other products concerned.

MR. McCANN: Mr. Conklin, I didn't have time to explain it, but their names are absolutely legion.

MISS HATFIELD: May I discuss the gist of that, because I feel that lack, too. It's a fact that there isn't time enough today to cover the tremendous field of plastic-coated fabrics which everybody uses on walls, furniture and so forth. Now, I would like to say one thing in closing. One hopes that the future of the plastics industry will be as exciting as it has been in the years past; it will be if this day is typical.

MR. HUNTZICKER: Thank you, Miss Hatfield, and thank you, Mr. McCann. Before the next part of the program, I am going to ask that all of the speakers who have spoken today come down here to the front so that they will be available to answer questions.

DISCUSSION OF THE FIRST DAY'S PROGRAM

MR. HUNTZICKER: The last item on our program today is a discussion of the first day's program, which will be moderated by Mr. C. Russell Mahaney. Mr. Mahaney is Vice President and Director of the St. Regis Sales Corporation and Vice President and Director of the St. Regis Paper Company, both of New York City. He is also Vice President and Director of the St. Regis Paper Company (Canada) Limited; general manager of the Panelyte Division of the St. Regis Paper Company; and Vice President and Director of the Cambridge-Panelyte Molded Plastics Company.

Mr. Mahaney pioneered in the production of decorative laminated plastics and was associated with the early development of laminated plastics for the appliance in automotive industries. He is a native of Maryland, a graduate of University of West Virginia with a Bachelor of Science degree in chemical engineering, and has a Master of Science degree, also. Mr. Mahaney. (Applause.)

MR. MAHANEY: Mr. Chairman and ladies and gentlemen: It is with a real significance that this magnificent conference has been sponsored by The Society of the Plastics Industry, Inc., Manufacturing Chemists' Association, Inc., and the Building Research Advisory Board, three great organizations who recognize a community of interest in sponsoring such a meeting.

In 1953 the production of resins for the plastics industry amounted to three billion pounds. The cubical volume of this tonnage exceeded the combined cubic volume of aluminum, brass, copper and all other nonferrous metals. Hence, we see plastics becoming of age. No longer are they a substitute material, but an engineering material in their own right.

I think it has been aptly poined out many times here today that plastics should be used only when they do the same job as the material they replace—at an equal or lower cost—or do a better job than the material they replace. Professor Dietz cited a great many uses for plastics, some new and some in the dream stage. Mr. Rogers gave us a realistic evaluation of the economies of plastics. He touched on where we are heading and, also, of what plus factors the plastics industry has to offer and showed us an understanding of the job which is to be done.

Mr. Berkson told us about light transmission and revised the concept of awnings (where we shut the light out) to through proper handling of the transfusion of light, bringing the light into the homes to the advantage and well being of the people and ensancing the beauty of these awnings.

Mr. Kennedy gave us a talk on the expanded plastics, foam plastics and vapor seals, and Mr. Waidelich gave us a view of the various plastic panels which certainly challenges our imagination as to the future.

Mr. McCann gave us an insight into the durability of plastic flooring and told us of the decorative melamine high-pressure surfaces, some of the background and evaluation of those products; also the polyester decorative surfaces.

I am certain that through these stimulating talks, we have created a desire for more questions about the entire day's meeting. I'd like to throw the meeting open now to questions about anything that has transpired during the day. The speakers will endeavor to answer it.

MR. ROBERT W. BARBER (St. Regis Paper Company): I would like to ask a question primarily of the material manufacturers. We have discussed some of the problems of thermoplastics and many of the advantages of thermoplastics. My question is what can we look to in the future in overcoming some of the disadvantages of thermoplastics, mainly in the line of heat resistance. I don't know to whom that should be directed, but any of the manufacturers may answer it.

MR. COOPER: This is no time to use a crystal ball. I think you realize that there are many things going on in research that we are not, in general, as manufacturers, ready to talk about yet. However, I think it is perfectly fair to say that many of us are concerned with the development of resins which will lead to plastics with a very increased resistance to the upper temperatures and to which the stiffness of polyester will be maintained over higher temperature ranges. I would like to point out that while the thermoplastics do soften upon heating (which, of course, leads to the formability and so forth that thermoplastics have), it is also true that there are a number of thermoplastics which can be used, and are being used, at temperatures which are considered high when one is dealing with thermostatic materials. Of course, when thermoplastics are combined with fillers (reinforcing fillers, fiberglas reinforcements and the like), it turns out that the resulting reinforced materials have properties which are quite comparable with those where the resin is a thermostatic resin.

MR. MAHANEY: Plastics is perhaps the fastest growing industry in America. In 1953 we increased the tonnage volume of resins 30 per cent over 1952. It is, however, fraught with many changes necessitating forward thinking, and prompt action at all times. Our own company, St. Regis Paper Company, entered the plastics field many years ago to find an outlet for paper. How very wrong that has been, because now the useage of paper in our various plastics plants is very small compared to our output of plastics.

In conclusion, plastics has a great responsibility to the building industry—and a real job to do. We in the plastics industry believe that we know our jobs. We are certain that you in the building industry know yours. We would request that you bring to the plastics industry your problems.

It has been demonstrated here today that the plastics industry has the courage to point out the weaknesses in plastics and also to emphasize the fact that those weaknesses are being corrected in the various research laboratories. Tell us your problems. Working together, we will attempt to solve them. Mr. Rothenstein?

MR. GUY G. ROTHENSTEIN (Architectural Consultant): I am industrial and architectural designer, and I act as architectural consultant to Progressive Industries, Inc., and Liquid Plastics Corporation in New York. Progressive Industries specialized in sprayed-on plastics. This is a recent development of plastics in building, and the interesting aspect of it is that unprocessed plastic is taken to a construction site, is applied there with construction labor.

Under this concept the application of plastics became a new craft, and material actually is formed by conventional materials on the job with appropriate tools. The type of plastic which up to now is the most developed to such uses is a vinyl chloride—vinyl acetate copolymer.

This material comes to the site in liquid form, and the tool used is a spray gun with 60 to 80 pounds pressure. It is applied in thicknesses varying from 20 to 40 mils, and it cures and forms a flexible sheeting with a tensile strength of over a thousand pounds per square inch and maintains an elongation factor of over 200 per cent. It can be applied to surfaces of almost every material and has an adhesion of 10 pounds per square inch or more, depending on the type of surface.

With a reasonable amount of maintenance this material lasts the normal lifetime of the building, indoors as well as outdoors. The most remarkable aspect of this plastic is that, applied to a structure, it forms a continuous sheeting or skin of any size or any shape which will follow all the movements of the structure.

To me, as a designer, this means that we have finally found an answer to the age-old problem of dejointing. The deficiencies of dejointing were pointed out several times during the conference in connection with panel construction. The full impact of this event means a complete change of almost all aspects of our present construction technology.

Designing with sprayed plastics affects structure, mechanical systems, especially heating and air conditioning and ventilation, it affects the selection of material, it affects the assembly of materials and color schemes.

Instead of going deeper into the subject, I would like to bring up some examples of recent application of sprayed plastics, or rather, buildings which design sprayed plastics. The most significant one is a 15-story hotel in Tyler, Texas, which is completely enclosed with a sprayed plastic. This building is designed without any additional veneer, such as brick. There are no copings, there are no flashings, and no caulking. It is quite an evolution in construction.

Similarly, sprayed plastics have been used by New York's Lever House under the soffit. The entire stucco area is covered with a single sheet about 15,000 square feet in size of a sprayed plastic.

The same material can be used indoors for wall covering, and the performance is about the same as calendered vinyls. The result is an absence of joints which lower costs. An application of this type has been made in New York University Medical Center, where the entire first floor has been sprayed with vinyl acetate.

Another major use is in roofing of large areas of complicated shapes. Here, the plastic is applied to various types of materials, such as concrete or metal. Recently the entire roof of the New York Central office building was re-roofed with sprayed plastic. What I object to is that the color specified was batino copper, but that is incidental.

Sprayed plastics are also used as vapor barriers. More applications are being developed every day by architects and designers using the economies inherent in designing with the sprayed plastics.

I find all of these elements most exciting, and the young industry of sprayed plastics is moving very rapidly, strictly on the basis of its own merits. Up to now, none of the larger companies has actively participated in this development.

MR. MAHANEY: Thank you very much, Mr. Rothenstein.

I think I would be remiss in closing if I didn't thank the speakers for the excellence of their papers and to congratulate the committees for the planning and execution of this fine meeting. Thank you. (Applause.)

PLASTIC PIPING

By Joseph S. Whitaker*

The Bakelite Company

THE use of plastic pipe in this country has been largely confined to the distribution of water in rural areas, mine drainage, gas distribution, and specialized industrial applications. In some localities building services such as gas, water, and electricity are delivered to the foundation walls of homes and plants through various types of plastic pipe, and sewage is carried away in plastic pipe, although very little plastic pipe has been used inside of buildings. These installations provide a useful background of service that will stimulate fuller utilization of the inherent light weight, corrosion resistance, and ease of handling of plastic pipe in building construction.

Several of the plastic materials that were reviewed earlier in the conference are used in the manufacture of pipe and fittings. Those most widely used are acrylonitrile copolymer blends, cellulose acetate butyrate, polyethylene, polyvinyl chloride (PVC), polyvinylidene chloride (Saran), and combinations of glass fiber with thermosetting resins.

This is a long list for an industry as young as the plastic pipe industry, but each of these materials has some special properties that are desirable in some areas of application. For example, PVC and Saran are the only two materials that are self-extinguishing; polyethylene is the lightest and most flexible of the group; and the glass-reinforced materials have the lowest thermal coefficient, very nearly matching the coefficient of steel. These and other physical properties are summarized in Table I.

POLYETHYLENE PIPE

Polyethylene has been the most popular plastic pipe material in recent years. The reasons for this popularity are its inherent flexibility, a past record of accepted use for food containers and food wraps, excellent resistance to breakage from mechanical shock even at temperatures below —40°F, chemical inertness, and light weight. Because polyethylene is flexible, pipe made from it (in sizes through three inches) is shipped in coils. These, and other commercial sizes listed in Table II, easily follow the contour of irregular ditches and rough terrain (Figure 2.4.1). Polyethylene pipe is also available in Schedule 80 wall and in new industry standard sizes issued by the Department of Commerce on October 15, 1954.

The chemical inertness of polyethylene is desirable in applications such as drain tubes for flue liners and piping in chemical plants; however, it prevents the use of solvent welded fittings. As a consequence, polyethylene pipe sections are usually joined with rigid insert-type fittings which are molded from a rigid plastic such as the copolymer mentioned above, or fabricated from a non-corrosive metal. The pipe is held onto the fitting with an adjustable stainless-steel clamp. Threaded male adapters, combining the insert on the plastic pipe side, are available through the six-inch nominal size.

Polyethylene has been widely used for the in-hole pipe pair in jet wells (Figure 2.4.2). The pipe is easy to handle without special tools or rigging equipment, and wells can be serviced in basements where rigid pipe would be awkward to maneuver. These conveniences save time and labor. Polyethylene pipe does not require protection from freezing and may be buried in shallow trenches.

The flexibility of polyethylene pipe is used to good advantage in a "take-up" skating rink in Detroit's civic center. An area of 85 by 120 feet, used as a tennis court in summer, is covered with a network of one-inch polyethylene pipe spaced four inches apart. The pipe circulates brine under 30 pounds pressure with initial surges of 40 pounds. Over 31,000 feet of pipe are used in the system, which cost an estimated $40,000. The project is practical because the pipe can be easily rolled up and stored at low cost during the summer months.

Permanent networks of polyethylene pipe have been used in radiant heating systems. A typical installation, in New Philadelphia, Ohio, used about 4,700 feet of one-inch pipe to cover an area 138 by 33 feet. The pipe was laid in eleven lines connected to metal manifolds with insert adapters and metal clamps. Four lines, spaced nine inches apart, ran around the outside perimeter of the area. The other seven lines were laid in the center area in egg-shaped loops, to prevent crimping, and were spaced 12 inches apart. L-shaped fittings on the extreme outside corners provided better coverage of the floor area. The pipe was

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FIG. 2.4.1: Flexible polystyrene pipe

held in place with canvas strips, tested for leaks under 50 pounds water pressure, and then covered with four inches of concrete. Water, heated to 115°F in a gas-fired boiler, is circulated through the installation with a high velocity Bell & Gossett pump. It has operated without difficulty through two winters.

The use of polyethylene pipe has been officially recognized in England for cold-water services, overflow, flush and warning lines, and pipe for use in chemical and food industries. Specifications covering these uses were published in 1953. They are British Standard 1972 and 1973.

BUTYRATE PIPE

Cellulose acetate butyrate pipe (Figure 2.4.3) is used for oil field applications where high paraffin crudes deposit solid wax in metal pipe and where severe corrosion problems exist. It is also used for lawn-sprinkler systems, and for gas service lines up to a building foundation wall. Because butyrate is semirigid, small-diameter pipe made from it can be handled in coiled 200-foot lengths. These coils, up to 1½ inches I.D. (inside diameter), are available

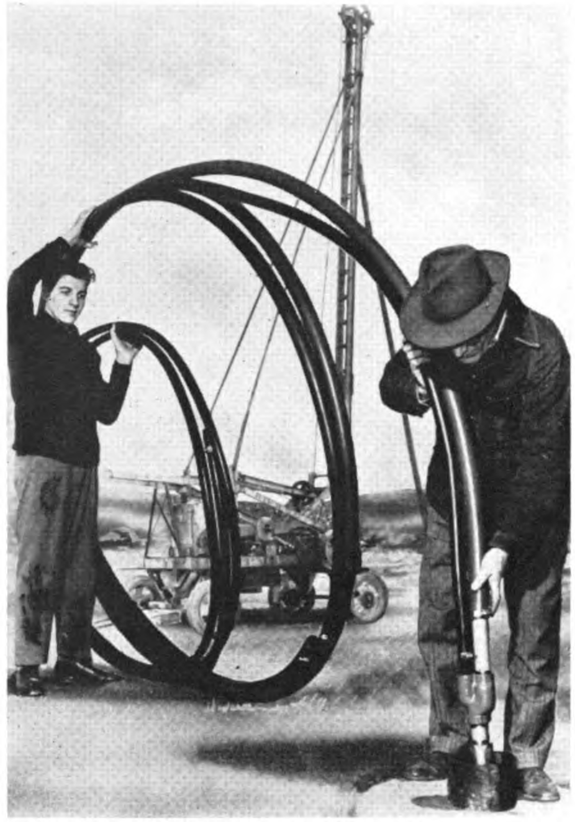

FIG. 2.4.2: Polystyrene pipe for jet well installation

in iron-pipe sizes as well as sizes having outside diameters similar to copper tubing. The latter are used for relining corroded gas service entrances.

One of the advantages of butyrate is that it is available as a clear, transparent material which permits inspection of pipe contents, as is often desired in food-handling equipment.

Fittings for butyrate pipe systems are the slip-sleeve type which are cemented to the pipe (Figure 2.4.4). Transparent fittings permit inspection of cemented joints (Figure 2.4.5). Plastic pipe joined in this fashion is known as "solvent welded pipe" (SWP).

The data in Table III indicate the safe working pressures of several sizes of butyrate pipe. The material is sensitive to temperature and loses strength as it is heated. This is also characteristic of polyethylene, polyvinyl chloride, Saran, and the copolymer blends.

All of the plastic pipe materials offer less resistance to flow than does steel. One-inch butyrate pipe, for example, will deliver about 50 per cent more water than clean steel pipe under the same head loss.

Butyrate pipe is, of course, resistant to corrosion. It has been used industrially to pipe highly carbonated ground water, salt water, and industrial wastes (Figure 2.4.6). It is usually buried below the frost line to prevent damage from freezing.

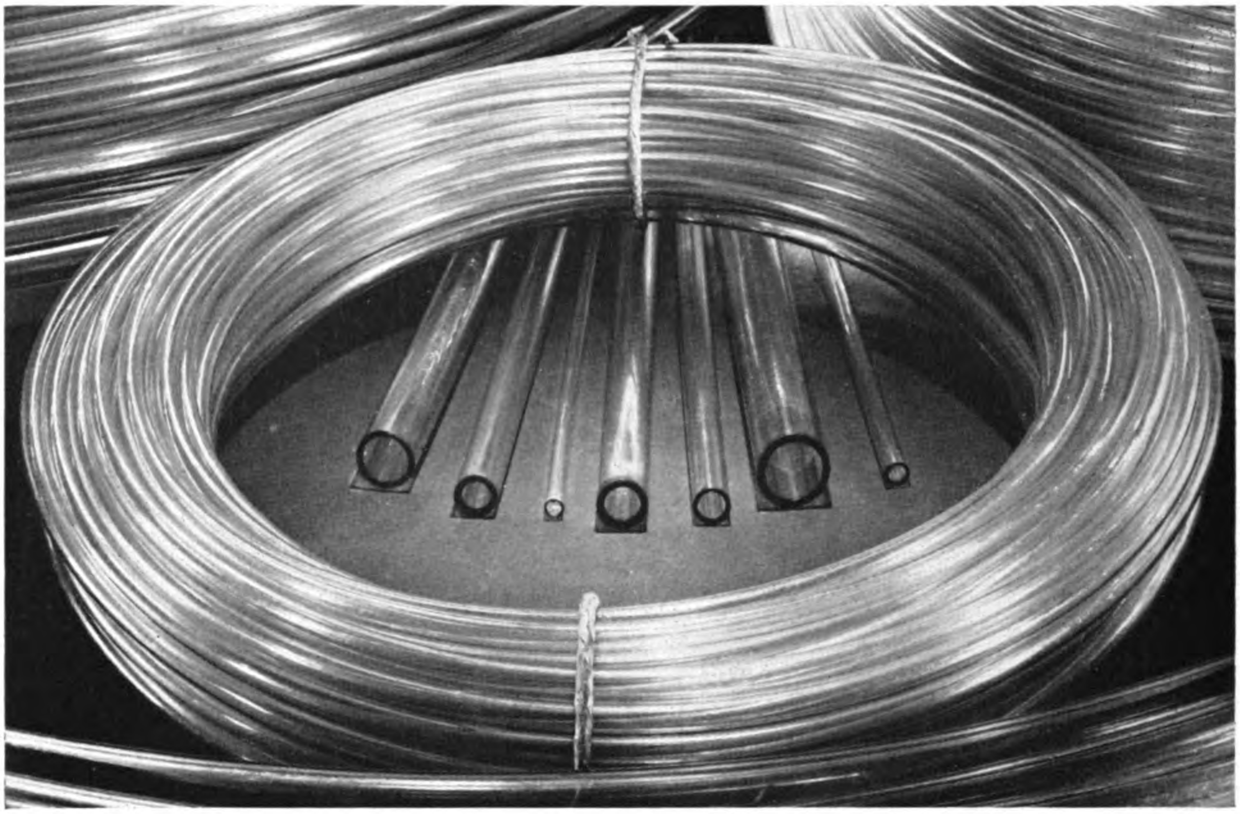

FIG. 2.4.3: Examples of cellelose acetate butyrate piping

COPOLYMER BLENDS FOR PIPE

The acrylonitrile copolymer blends are rigid plastic materials about 10 per cent lighter than butyrate and about one-seventh the weight of steel. Pipe made from copolymer blends is available in standard and extra heavy wall iron-pipe sizes. The physical characteristics of standard wall pipe are shown in Table IV. Extra heavy wall pipe has twice the working pressures shown in the table for both 70°F and 170°F service.

This pipe is usually threaded, as are the fittings and adapters used with it; however, it can be solvent welded. Both pipe and fittings are produced from the same copolymer blend. Fabricated Saunders-type diaphragm valves are also available in one-half inch through two-inch sizes. These valves are recommended for use over the same temperature range as the pipe—a maximum of 170°F and not to be exposed to physical abuse below 20°F.

All of the advantages of rigid pipe, such as the fact that it requires minimum supports in overhead installations, are inherent in copolymer blend pipe. It has been widely used in industrial applications to combat corrosive conditions where metal pipe replacement is frequent and where a material with higher impact resistance than glass pipe is desirable. Typical applications that are giving satisfactory service are a spray tower line handling 170°F dilute sulfuric acid, outlet lines for wet chlorine on electrolytic cells, bleach solution lines in paper mills, and drum-filter lines in sewage-disposal plants handling acidic ferric chloride solutions. This pipe is probably entirely satisfactory for sewage disposal and other domestic drain lines in its current state of development.

One of the advantages of exterior plastic disposal lines is that they can be assembled above ground and then quickly buried in narrow trenches. The ground opening can be almost as narrow as the outside diameter of the pipe. In low areas where water seepage presents a problem, these lines can usually be buried before the trench floods.

POLYVINYL CHLORIDE PIPE

Polyvinyl chloride pipe (PVC) and fittings have been used extensively in Europe for over 20 years. Chemical plant piping, handling acid solutions and gases, has been in service for 15 years; gutters and down spouts in corrosive atmospheres have been used for over seven years. Rigid polyvinyl chloride suitable for the manufacture of pipe and fittings has been available here only a few years, and experience with this type of plastic pipe is limited. However, in view of the successful use of these materials abroad, even when exposed outdoors, it is probable that PVC pipe and fittings will be rapidly adopted for such uses as drain lines, down spouts, and sewage-disposal lines.

FIG. 2.4.4: Injection molded butyrate pipe fittings

Extruded PVC pipe and fittings are now available in the sizes shown for butyrate in Table III but with different working pressures; in Schedule 40 iron-pipe sizes through four inches; and in heavier wall Schedule 80 iron-pipe sizes through four inches. Typical PVC data for heavier wall pipe through two inches are summarized in Table V.

PVC pipe has unusually good ductility for a rigid plastic material. It is easily threaded or flared to form the female portion of a bell and spigot joint, which is usually cemented to form a permanent connection. PVC can be welded using a hot gas stream and a PVC rod. Good pipe joints are formed by welding butt ends and by welding external sleeves or flanges over the end of pipe. Correct alignment is more important with PVC pipe than with types of plastic having higher impact resistance. It changes dimensions with temperature changes about seven times as fast as steel. Provision must, therefore, be made for movement of the pipe with temperature changes in order to avoid excessively high stresses, or wide temperature variations must be avoided by burying or otherwise insulating the pipe. The magnitude of the stresses caused by temperature changes is about 900 psi for a change of 120°F. Rigid PVC has good outdoor weather resistance and is self-extinguishing.

SARAN PIPE

Polyvinylidene chloride (Saran) is similar to PVC in physical and chemical properties. Pipe made from Saran is available in the sizes shown in Table VI,

FIG. 2.4.5: Slip sleeve coupling for butyrate pipe

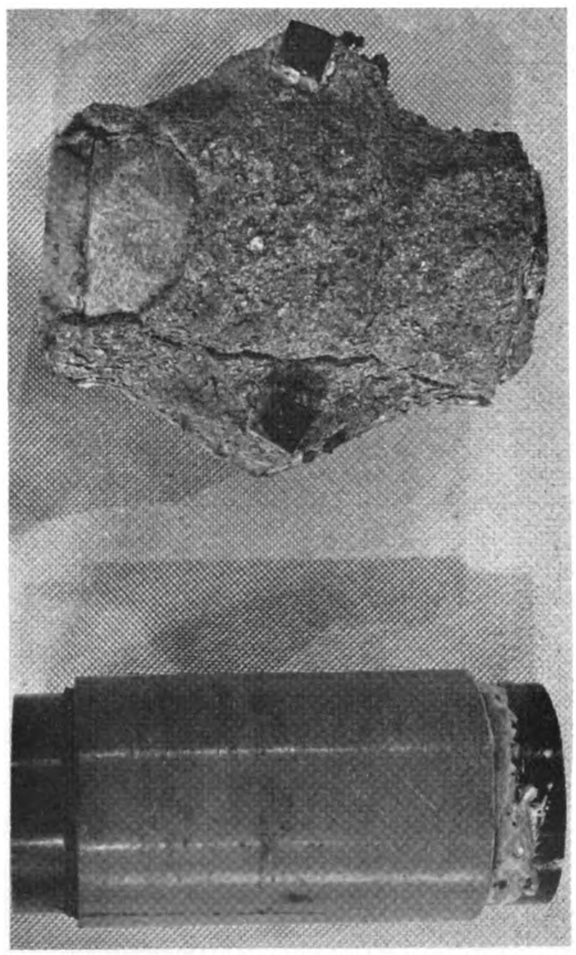

FIG. 2.4.6: Aluminum coupling (top) and reinforced plastic coupling after six months in salt-laden ground.

TABLE I

PHYSICAL PROPERTIES OF PLASTIC PIPE MATERIALS

Kind of Material	Specific Gravity	Tensile Strength psi @ 75°F	Tensile Modulus psi x 10^{-3}	Elongation at Break, Per Cent	Notched Impact Strength	Working Tensile Strength (a) @ 75°F	Thermal Expansion in./in. per °F x 10^{-6}	Thermal Conductivity BTU/hr/ sq. ft./ °F/in.	Flammability
Polyethylene	0.92	1,500	19	400	16	400 to 550	10	2.3	Burns slowly
Acrylonitrile Copolymer Blend	1.06	5,000	270	30	7	850 to 1300	5.0	1.0	Burns slowly
Cellulose Acetate Butyrate	1.20	5,000	132	54	2	700 to 1100	7.5	1.7	Burns slowly
Polyvinyl Chloride	1.40	6,500	400	12	0.8	1500 to 1600	4.0	1.2	Self-extinguishing
Polyvinylidene Chloride	1.70	5,000	100 to 200	15 to 25	2	700	4.0	1.0	Self-extinguishing
Glass Fiber Reinforced Resin	2.0	11,000	1000	Very Low	—	1600	1.1	2.3	Burns slowly

(a) Calculated from pipe manufacturers' recommended working pressures.
These figures include safety factors applied by pipe manufacturers and are not in every case true working tensile strengths of the plastic material.

TABLE II

POLYETHYLENE PIPE DATA

Nominal Pipe Size: Inches	OD Inches	ID Inches	Weight Lbs./ft.	Bursting Pressure psi, 75°F	Recommended Continuous Working Pressure to 140°F	Lengths, ft.	OD Coil Diameter Inches
½	.840	.622	.103	450	135	400	33
¾	1.050	.824	.132	360	110	400	38
1	1.315	1.050	.194	275	80	300	48
1¼	1.660	1.380	.272	250	75	300	54
1½	1.900	1.610	.326	210	65	250	60
2	2.375	2.067	.434	180	55	200	78
2½	2.875	2.469	.690	175	50	200	85
3	3.500	3.068	.907	170	50	100	96
4	4.500	4.026	1.293	160	48	25′ straight	
6	6.625	6.065	2.275	115	35	25′ straight	

together with a complete line of threaded fittings including flanges. Saran tubing and flare-type fittings are also made in standard sizes ranging from ⅛-inch to ¾-inch outside diameter with special sizes available on request. Among its other industrial applications Saran may be used for gasoline fuel lines.

During the past year, one of the plastic pipe manufacturers introduced a line of sewer and drain pipe in standard wall, two, three, four, five and six-inch sizes; heavy wall, four inches; and a light wall perforated four-inch size. The solid pipe is used for domestic sewer connections between the exterior basement wall and septic tanks, and beyond the septic tank to the gravel pit. The perforated pipe is used beyond the gravel pit. Sleeve-type couplings, adapters, and T-connectors are cemented onto the pipe to form a continuous I.D. tube. The pipe material has not been identified, but the price indicates that it is one of the thermoplastic materials mentioned above.

GLASS-REINFORCED PLASTIC PIPE

An entirely different type of plastic pipe from those discussed previously is manufactured from thermosetting resin and oriented glass fiber. This is the strongest plastic pipe produced to date, and it can be used at higher service temperatures. The glass fibers reinforce the otherwise brittle resin and impart a high degree of impact resistance, even at —65°F, in combination with rigidity.

The techniques used in the manufacture of glass-reinforced pipe are new, are costly, and are constantly being improved. The intensive development effort in this area holds promise for a more versatile, non-corrosive pipe having mechanical properties that will permit it to be widely used in plumbing. Even at its present high cost this is an excellent pipe for specialized applications. The pipe is available in 20-foot sections and in sizes shown in Table VII. These are the sizes used in oil fields. Pipe sections are coupled with threaded sleeves which are cemented with the same type of resin used in the pipe.

TABLE III

SOLVENT WELDED BUTYRATE PIPE

Nominal Pipe Size: Inches	OD Inches	ID Inches	Wall Thickness Inches	Estimated Safe Working Pressures: Pounds Per Square Inch 180°F	120°F	60°F
½	.60	.50	.050	67	133	199
¾	.855	.75	.052	48	96	143
1	1.14	1.00	.070	48	96	143
1¼	1.42	1.25	.085	46	93	139
1½	1.73	1.50	.115	52	104	156
2	2.25	2.00	.125	43	87	129
2½	2.57	2.32	.125	38	76	113
3	3.25	3.00	.125	30	61	90
3½	3.66	3.36	.150	32	65	97
4	4.10	3.80	.150	29	58	87
5	5.11	4.75	.180	28	57	85
6	6.22	5.76	.230	29	58	87

These estimated safe working pressures have been calculated at 20 per cent of actual bursting pressures.

TABLE IV

STANDARD WALL ACRYLONITRILE COPOLYMER BLEND PIPE

Size IPS: Inches	OD Inches	ID Inches	Weight Lb./ft.	Working Pressure psi 70°F	170°F
½	0.840	0.622	0.12	150	75
¾	1.050	0.844	0.16	150	75
1	1.315	1.049	0.23	125	60
1¼	1.660	1.380	0.31	100	50
1½	1.900	1.610	0.37	90	45
2	2.375	2.067	0.50	75	40
3	3.500	3.068	1.04	60	30
4	4.500	4.026	1.50	60	30
6	6.625	6.065	2.62	50	25

Standard length: 20 feet and 10 feet.

TABLE V

SCHEDULE 80 RIGID PVC PIPE

Nominal Pipe Sizes: Inches	OD Inches	ID Inches	Weight Lbs./ft.	Bursting Pressure psi	Recommended Working Pressure psi to 160°F
½	.840	.546	.200	1635	150
¾	1.050	.742	.2675	1375	125
1	1.315	.957	.418	1275	125
1¼	1.660	1.278	.541	1095	125
1½	1.900	1.500	.743	985	100
2	2.375	1.937	1.027	860	100

TABLE VI

SCHEDULE 80 POLYVINYLIDENE CHLORIDE PIPE

Nominal Size: Inches	OD Inches	ID Inches	Weight Lbs./ft.	Bursting Pressure psi @ 77°F	Working Pressure psi @ 77°F
½	.840	.546	.236	1300	260
¾	1.050	.742	.320	1060	210
1	1.315	.957	.475	970	190
1¼	1.660	1.278	.650	820	160
1½	1.900	1.500	.790	740	150
2	2.375	1.939	1.090	620	125
2½	2.875	2.277	1.805	570	115
3	3.500	2.842	2.480	510	105
4	4.500	3.749	3.760	460	90
6	6.625	5.761	6.326	400	80

TABLE VII

GLASS REINFORCED PIPE SIZES

Size: Inches	Class	Wall Thickness	Recommended Operating Pressure psi	Bursting Pressure psi	Weight per 20-foot Section: Pounds
2⅞	100	.20	100	900	19
2⅞	200	.215	200	1,200	20
3½	100	.20	100	800	26
3½	200	.215	200	1,200	28
4½	100	.23	100	900	40
4½	200	.25	200	1,200	42

GENERAL DISCUSSION

MR. HUNTZICKER: Thank you, Dr. Whitaker. The question-and-answer period will be moderated by Mr. Chester Brownell, President of the Reliable Plumbing and Heating Company of Champaign, Illinois. He is Past President of the Illinois Master Builders Association and Past National Secretary of the National Association of Plumbing Contractors. Mr. Brownell.

MR. BROWNELL: Mr. Chairman, ladies and gentlemen: I can tell by the looks on your faces that you are wondering how a plumber ever got on the program. I know I began to wonder that myself a short time ago when my good friend, Bill Schieck, called me and asked me if I would take part in this program. I told Bill that I was not too familiar with plastic piping. We had used some; not very much. However, when I arrived here yesterday and looked around—at the moment I am looking at the display that the plastics people have put up—I concluded that our industry was pretty well represented. The question period is open for discussion.

MR. I. W. MENDELSOHN (U. S. Department of Interior): I understand that at the University of Michigan a committee has been working for a year or more, making tests on different kinds of plastic pipe for water and sewage, and also, I think, oil and gas. I wonder if Mr. Whitaker will give us some of the latest findings of this committee with regard to the use of plastics for these purposes.

MR. BROWNELL: Dr. Whitaker?

DR. WHITAKER: Mr. Mendelsohn, I can't give you the latest report on that. The work will be reported only through the National Sanitation Foundation at the University of Michigan. An interim report, however, was delivered by Dr. Teeterman in a talk before the American Waterworks Association in Seattle last May.

Briefly, the project of the commission is to evaluate plastic materials for transporting potable water. (Oil and gas are not included in that program). We in the plastics industry don't know now whether the plastic materials that are being used, or will be used in the foreseeable future, represent a public-health hazard when used with potable water. That program, I believe, will be terminated about the end of this year. There should be a report in early 1955.

MR. BROWNELL: There's a question from the floor?

MR. GERALD W. WALRAFEN (B. F. Goodrich Company): I notice with interest that plastic pipe is being used in radiant heating systems. I am wondering how it compares with other pipe materials in regard to spacing, depth of burying, and depth of cover. In other words, is the same design used in plastic pipe as would be used in other types of pipe that we know of?

DR. WHITAKER: The design is roughly the same as is used with other types of pipe. The concrete barrier, I think, is of the same order of magnitute as it would be with copper tubing. I think the only significant difference is that water normally circulates through the plastic tubes at a little higher rate than in copper tubes.

MR. H. W. DAILEY (Tubular Plumbing Goods Institute): I am interested in the possible use of plastic pipe for making sink traps and non-corrosive equipment. Can that be considered in the future, and if so, will there not have to be changes in various city ordinances, pumbing codes, etc.? Will you give me information on that?

MR. BROWNELL: You were interested in plastics for such items as sink traps?

MR. DAILEY: Yes, sir.

MR. BROWNELL: Dr. Whitaker?

DR. WHITAKER: I think there will have to be changes in codes to permit the use of plastic material for sink traps. It's coming, I believe, and on the theory that plastics are available, I believe they are suitable for that type of application.

MR. DAILEY: In the sink traps, do you have a plastic design today that will take a wide spread in water temperature? In other words, very cold water and very hot water going through the same trap?

DR. WHITAKER: Is not the design of a sink trap such that you have a natural expansion joint, or natural expansion hoop? The thermoplastic materials expand approximately seven times as fast as metal. The glass-reinforced plastic materials expand at about the same rate as metal, but pick one that expands substantially with temperature change. I would guess that the design of the trap would take care of temperature variation.

MR. E. E. GRUBER (General Tire and Rubber Company): We have had reports that the melting point of polyethylene has been raised either by irradiation or by new processes. If the melting point is raised approximately 30 degrees, can polyethylene be used for conducting hot water, in your opinion?

MR. BROWNELL: I don't know whether you are speaking of hot water domestically or in a heating plant, though the answer may be the same for both. Dr. Whitaker?

DR. WHITAKER: Polyethylene has some strength at 180 degrees Fahrenheit. In other words, that is not the zero strength temperature-point for the material. So, if properly designed, polyethylene could be used in systems that were protected against temperature rises above that. However, I think the design, as stated, is somewhat impractical. Irradiated polyethylene with the working temperature range raised 30 degrees certainly could be used in hot-water systems. But it would be quite impractical, because the cost of irradiated 125 mil wall at this stage would probably approximate that of platinum or gold.

MR. GRUBER: What pipe would you recommend for above-ground installation outdoors; that is, that would be weather-resistant?

DR. WHITAKER: It depends on how long the material is to be used above ground outdoors. None of these polyethylene materials could be used indefinitely. However, some polyethylene pipe is currently used for water distribution on farms and for irrigation water, and the pipe is not buried. Generally all plastic pipe is buried against deterioration from sun.

MR. DAVID CRAIG (The Ontario Paper Company, Ltd.): Are these plastics resistant to bacterial action? I am thinking particularly of the type of bacteria in the pulp and paper mill stockroom.

DR. WHITAKER: Deterioration from bacterial action is not generally considered to be a hazard for any of these plastic pipes.

MR. BROWNELL: We have time for one more question. Yes?

MR. R. M. PAULSEN (United States Rubber Company): Can you say anything about the tendency for field animals to eat the various kinds of plastic pipes?

DR. WHITAKER: Animals show no tendency to prefer it to other materials, such as lead or wood. Any material is apt to be destroyed by rodents or other gnawing animals. If a telephone cable is in the way, they will gnaw it.

MR. BROWNELL: I'm sorry, but our time is up. Thank you very much, gentlemen.

MR. HUNTZICKER: Thank you, Dr. Whitaker and Mr. Brownell.

PLASTIC DUCTS AND CONDUITS

By Raymond B. Seymour*
Atlas Mineral Products Company

THE housewife recognizes the differences among various types of chinaware; likewise, the metal artisan differentiates between copper, zinc, and aluminum because he is acquainted with their specific properties. He also recognizes the advantages and limitations of galvanized and enameled metal sheet, as well as various alloys. Unfortunately, too few have a similar viewpoint about plastics.

Many talk about the possible application of plastics, but very few recognize the physical and chemical characteristics of the many different products included in this group. Obviously, a discussion of the application of plastics for ducts and conduits would be of little value without an elementary knowledge of the properties of the many available plastic materials. Hence, an attempt will be made to supply the minimum knowledge required.

PROPERTIES OF PLASTICS

Many different types of thermosetting and thermoplastic materials have been used successfully as ducts and conduits for at least 15 years. Both types of products have been used extensively in Europe, but, until recently, applications in the United States were limited to filled or laminated thermosetting plastics.

As indicated by the data in Tables I and II, a wide selection of plastic construction materials suitable for ducts and conduits is now available in this country. Proper attention to the physical and chemical properties of these products will aid the user in the selection of the appropriate material for any specific service. (Tables I and II on pages 85 and 86.)

However, it must be emphasized that the proper selection, design, fabrication, and installation of plastic ducts require expert knowledge. Obviously, those who subscribe to the *Statement of Principles by the Plastics Industry* should be in a position to make unbiased recommendations based on such knowledge. The statement is as follows:

"Plastic materials challenge industry with new concepts of design, engineering, construction, processibility and usefulness.

"The properties of plastic materials, when correctly used, open up great new areas of service to industry and the public.

"Improper use can do irreparable damage to the plastics industry, to both manufacturers and processors of the materials.

"Therefore, we as manufacturers and processors of plastic materials reaffirm our adherence to the principles upon which the healthy growth of a great industry depends and undertake to:

"I. Understand thoroughly the properties and limitations of all plastic materials handled by us;

"II. Apply the correct plastic materials to all industrial end uses, designing and engineering them for maximum value, performance and safety;

"III. Use great care to select the correct plastic materials for all consumer items, designing and engineering them to insure value, satisfaction, safety and pleasure to all users;

"IV. Sell plastic materials, and all industrial and consumer items made therefrom, on the merits of the materials, applications and design, and free of extravagant, insupportable claims.

"All to the end that plastic materials already available, and others that may come, will bring to industry and public alike all the benefits, economies and satisfactions inherent in these versatile engineering and construction materials."

While some structural plastics are known best by trade names, only generic names will be used in this discussion. However, a trade name list has been included at the end of this text and may be used as a guide by those unfamiliar with the generic nomenclature for specific plastics. Obviously, it is impossible to ascertain that a trade name list of products in a dynamic industry is complete. While every attempt has been made to include all known commercial

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trade names, the absence of any specific brand name should not be interpreted as a condemnation of any proprietary plastic material.

SPECIFIC PLASTIC MATERIALS

Polyethylene: Polyethylene has the lowest specific gravity of any available plastic material. It is not attacked by nonoxidizing acids, salts or alkalies. Since it tends to swell at ordinary temperatures and dissolves at elevated temperatures in many organic solvents, it is not usually recommended for this type of service. It has a coefficient of expansion of 10×10^{-5} in./in./°F. and should not be used continuously at temperatures as high as other thermoplastic materials of construction.

Unpigmented polyethylene deteriorates slowly in outdoor service but this product is satisfactory for use in direct sunlight when compounded with properly dispersed carbon black and suitable antioxidants. As indicated in Table I, polyethylene burns readily. It is one of the most widely used plastic materials and while satisfactory for many pipeline installations is not usually recommended for duct work because of its flexibility.

Heavy polyethylene sheet may be produced by extrusion or pressing. It may be heat-formed and thermally welded to produce ducts. However, such ducts are not rigid and usually require additional support.

Polyethylene welds tend to crack in the presence of some solvents and corrosives, but this property is less noticeable with carbon-filled high molecular weight products. Considerable information on polyethylene fabrication techniques has been developed by the Polyethylene Task Committee of the Thermoplastic Structures Division of The Society of the Plastics Industry, Inc.

Polyfluorocarbons: As shown by data in Table I, polytetrafluoroethylene and polymonochlorotrifluoroethylene are not attacked by solvents, acids, salts or alkalies even at temperatures as high as 400° F. Polytetrafluoroethylene withstands higher temperatures and is more resistant to hot concentrated nitric acid than polymonochlorotrifluoroethylene but, in general, the two materials may be discussed under one heading.

Polyfluorocarbons are more expensive and have a higher specific gravity than other plastics. They can be thermally welded to form duct work, but the cost of such equipment is generally too high to justify its use. As discussed subsequently, unplasticized polyvinyl chloride duct work is much less expensive and usually adequate for fumes from most industrial processes.

Polyvinyl Chloride: Millions of pounds of unplasticized polyvinyl chloride have been used successfully for 20 years in Germany. This type of product is now available in this country. Since its introduction to American industry, it has lived up to its European reputation as an outstanding material of construction for ducts and conduits. However, only one-tenth as much unplasticized polyvinyl chloride duct work was used in this country as in Germany in 1953.

According to the standards established by the Thermoplastic Structures Division of The Society of the Plastics Industry, Inc., the product comparable to typical German material is termed Type I. It has an Izod impact resistance in the order of one foot-pound per inch of notch and is resistant to all salts, alkalies and nonoxidizing acids at temperatures up to 150°F.

More recently, unplasticized polyvinyl chloride with an impact resistance as great as 15 foot-pounds per inch of notch has been introduced in this country. One of these products is a blend of polyvinyl chloride and acrylonitrile rubber. These products, which are classified as Type II, are slightly less resistant to oxidizing acids than Type I, but are satisfactory for use with many corrosives. For simplicity both types will be discussed together.

Because of its excellent physical and chemical properties, unplasticized polyvinyl chloride has been the preferred material for the fabrication of plastic industrial exhaust systems (Figure 2.4.7). Heavy sheets as wide as four feet and as long as nine feet are produced by calendering 20-mil film and laminating multiples of these thin sheets under heat and pressure.

Polyvinyl chloride sheets may be sawed, drilled, routed, deep-drawn, and thermal-welded. Thus, with the aid of standard mandrels and modifications of sheet metal and woodworking techniques, it is possible to produce a large variety of structures from unplasticized polyvinyl chloride. This duct work can be designed so that it is self-supporting. It is usually flanged in standard lengths and joined with flexible plastic gaskets held together by plastic or metal alloy bolts.

While complete creep data at all useful temperatures have not been published, much of the required data is available to fabricators of proprietary materials. Obviously, those guaranteeing the design of unplasticized polyvinyl chloride structures must have access to these data.

Saran: Saran was one of the first chemically resistant plastics to be extruded but its use as duct work has been very limited. It has a relatively high specific gravity and is resistant to many salts and acids at temperatures up to 150°F. It is attacked by chlorine, ammonia, organic amines and nitric acid.

Styrene Rubber Plastic: Styrene rubber plastic is resistant to salts, alkalies and nonoxidizing acids at temperatures up to 150°F but is less resistant than polyvinyl chloride to oxidizing agents. Sheets of this material can be cemented to form duct work. The corners are usually held together with extrued angles of the same material. As might be expected, these and many other plastics used for duct work construction are known better by trade than by generic names.

Epoxy Resins: Epoxy resins are prepared by reacting epichlorohydrin with bispenol A, the product

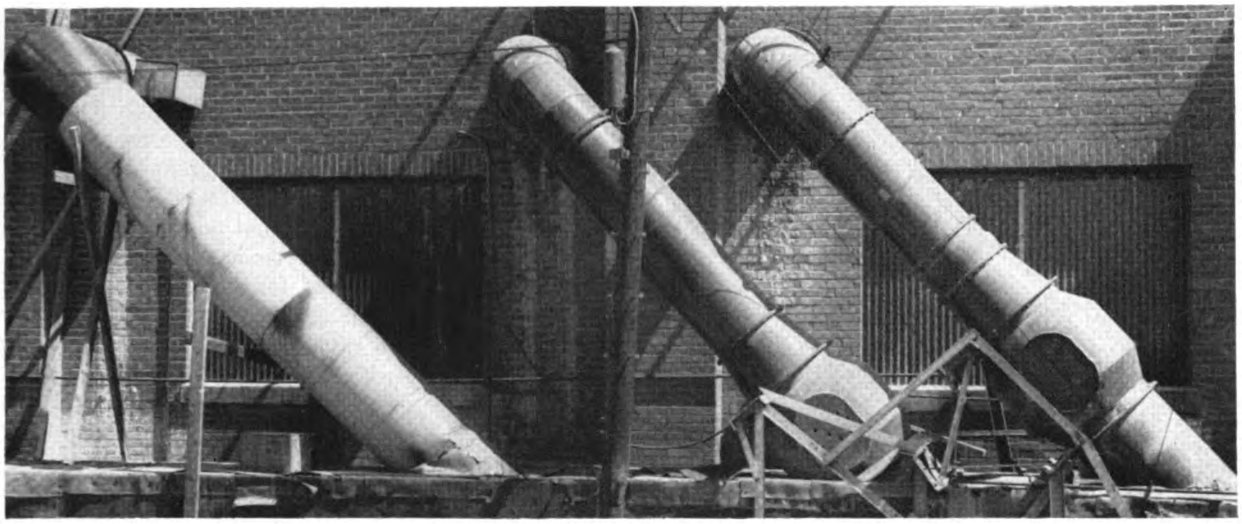


FIG. 2.4.7: Metal duct work (left) failed in three weeks; two plastic ducts on right have three-year service record

obtained by the condensation of acetone and phenol. While epoxy resins may be modified in many different ways to form coatings and adhesives, the products of greatest interest as materials for duct work construction are glass fabric reinforced liquid resins cured with aliphatic polyamines at room temperature or with other curing agents at higher temperatures.

As shown in Table II, epoxy resins have excellent resistance to nonoxidizing acids, such as hydrochloric, phosphoric and dilute sulfuric acid. They are suitable for use with gasoline and alcohols but should not be used with acetone or chlorinated hydrocarbons except at room temperature. In spite of their high cost, epoxy resins will be used to a greater extent than any other thermosetting resin for chemically resistant exhaust systems in the future.

Furans: Carbon-filled furan resins were first introduced commercially in 1941. While their principal use has been in the form of chemically resistant cements, variations of these formulations have been used to form heavy duct work.

Prior to the introduction of polyfluorocarbons, furan duct work was one of the most chemically resistant plastic structures known. These products are not attacked by alkalies, solvents, salts or nonoxidizing acids at temperatures as high as 350°F. They are not resistant to nitric acid, chromic acid or concentrated sulfuric acid. They are much heavier than other plastic structures. However, fiberglass reinforced furan resins continue to show promise for some types of industrial exhaust systems.

Phenolic Resins: While phenolic laminates can be prepared by hand-lay-up methods, using low-temperature curing resins, it has been standard practice to heat-cure such compositions in presses or on steel mandrels. These products have good resistance to nonoxidizing acids, salts, and solvents but are not recommended for use in alkaline service. While phenolic laminate duct work has been used to a limited extent, epoxy or polyester laminates are usually preferred by the chemical process industry.

Polyesters: In spite of their known lack of chemical resistance to liquid corrosives, fiberglas polyester laminates have been promoted widely for use as ducts. Because of the low concentration of corrosives in many exhaust systems, some polyester duct work has been completely satisfactory. However, since all commercial resins produced prior to 1954 were rapidly attacked by alkalies and many acids, there were many failures when actual liquid contact occurred, particularly at elevated temperatures.

Recently, resins which approach the chemical resistance of epoxy resins and retain the low cost of polyesters, have been introduced commercially. They consist of styrene solutions of esters formed by the reaction of fumaric acid with the product obtained through the condensation of bisphenol A and ethylene oxide or propylene oxide.

Duct work fabricated from these improved fiberglas reinforced polyester resins is more resistant to most chemicals than structures previously available. However, as shown in Table I, they are not completely resistant to alkalies or oxidizing agents. As noted in Table I, flame-resistant polyester structures are also available commercially.

APPLICATION DATA

Since plastic pipe was discussed in a previous report, some may want to know the fundamental difference between plastic pipe and duct of the same outside diameter. For simplicity, it is suggested that one consider primarily the relative ability of the two different structures to withstand pressure.

While there will be some overlapping between the two applications, this discussion will be limited to nonliquid systems operating at pressures of less than 20

FIG. 2.4.8: Welding rigid polyvinyl chloride duct work.

pounds per square inch. Thin-walled circular thermoplastic conduit or duct work is being extruded in this country in sizes up to eight inches outside diameter. Larger sizes are being extruded in Europe, and it can be expected that sizes as large as 20 inches will be available in this country within the next 18 months.

Rectangular and large circular duct work is fabricated from thermoplastic sheet stock. Such stock is usually produced by calendering thin sheets and laminating several of these sheets with heat and pressure to form heavy structural materials. It should be pointed out that it is standard practice to extrude heavy sheets of polyethylene and styrene rubber plastics, and presumably all thermoplastics may be extruded by such techniques in the future.

Regardless of how they have been produced, thermoplastic sheets may be softened by heating and formed to produce duct work. Rectangular sections are usually formed through the use of a bending brake; large circular duct work is rolled on a mandrel while warm.

Rectangular and circular ducts may be cemented or thermally welded to form complete sections (Figure 2.4.8). Since polyethylene and polyvinyl chloride are readily welded by heat, the heat-welding process is the one customarily used for joining these materials. However, it is customary to join styrene rubber plastic duct work with extruded strips, which may be cemented in place with an appropriate cement.

In general, plastic duct work exhibits much lower resistance to liquid and gaseous flow than most other materials of construction. However, when a completely gas-tight system is required, only thermal welded systems should be considered, even though sections joined with extruded strips are less expensive.

As evidenced in Figures 2.4.9 and 2.4.10 of complicated duct systems, there is practically no limit to the types of structures that can be constructed utilizing formed and heat-welded thermoplastics. It is customary to bolt flanged sections together using plastic or metal alloy bolts. However, a bell-and-spigot type of construction, joined by a plastic cement, may also be used advantageously in some applications.

In order to present a complete story on the application of thermoplastic materials in duct work, it should be mentioned that polyvinyl chloride and other resins may also be applied as coatings for the protection of metal exhaust systems. In isolated instances, the metal base consists of sheet metal dipped in a vinyl plastisol and heat cured.

All the thermosetting plastics listed in Table II may be filled with fibers such as asbestos and cast to form

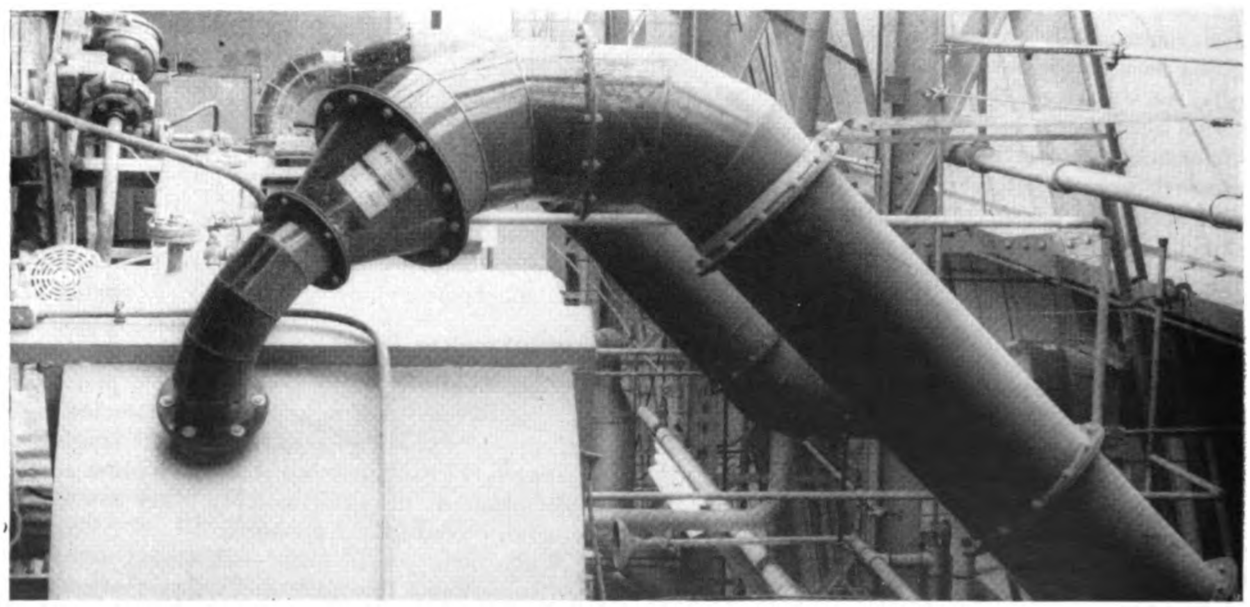


FIG. 2.4.9: Type I polyvinyl chloride fume duct system

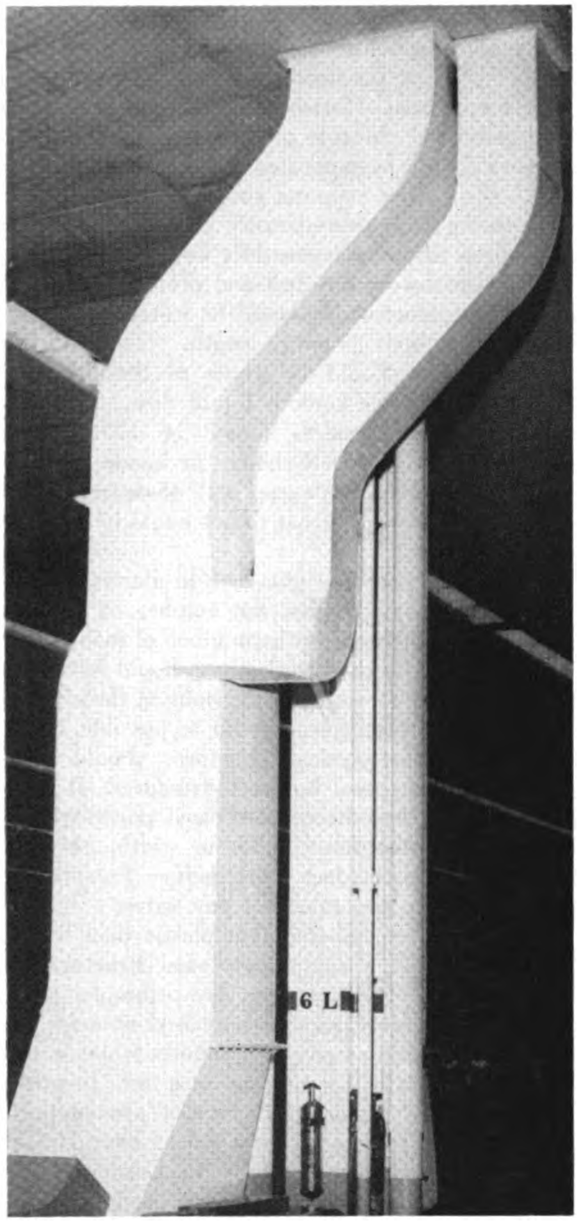


FIG. 2.4.10: Type I polyvinyl chloride exhaust system

duct work. However, in spite of the utility of such materials, they are heavy and are being replaced in many instances by fiberglas-reinforced plastics or thermoplastic structures.

The most widely publicized thermosetting plastic structures consist of glass cloth or glass mat impregnated with styrene solutions of unsaturated polyester resins. Standard polyester structures are not satisfactory for liquid acid or alkaline service but when cured properly are acceptable for some exhaust systems.

Special chemical and flame-resistant polyester formulations are available. While, as shown in Table I, the use of most thermoplastics is restricted to services at temperatures below 160°F, the glass-reinforced

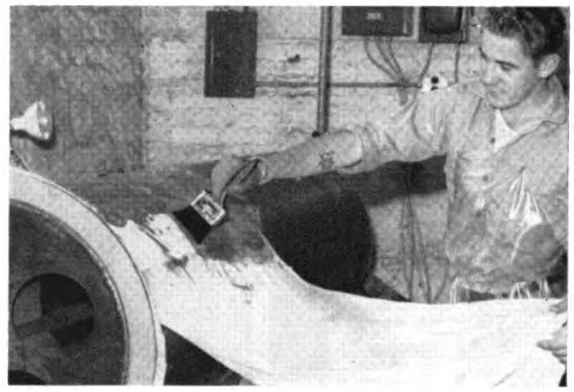


FIG. 2.4.11: Fabricating a polyesther glass reinforced duct using woven glass cloth and chemical resistant polyesther resin.

thermosetting plastics may be used at temperatures above that of boiling water.

Polyester or epoxy resin duct work may be formed by wrapping a mandrel with fiberglas fabric or mat impregnated with an appropriate catalyzed resin. As in the case of the thermoplastic materials, it is customary to use flanged sections of standard lengths for duct work construction. Several units produced by this technique are shown in Figures 2.4.11 and 2.4.12. It should be pointed out that the straight-end duct sections may also be joined by a simple wrapping technique.

DESIGN PROBLEMS

As is apparent from the temperature limitations outlined in Tables I and II, no reasonably priced duct work can be recommended for use at temperatures much above the boiling point of water. Because of their inherent high coefficient of expansion and tendency to creep, new design concepts must be applied for plastic materials of construction.

The design problems for plastics are similar to those encountered with metals at temperatures in the order

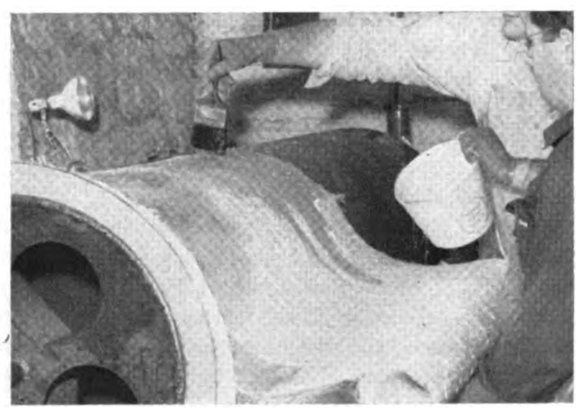


FIG. 2.4.12: Fabricating a polyesther glass reinforced duct by impregnating a glass mat with a flame resistant polyesther resin.

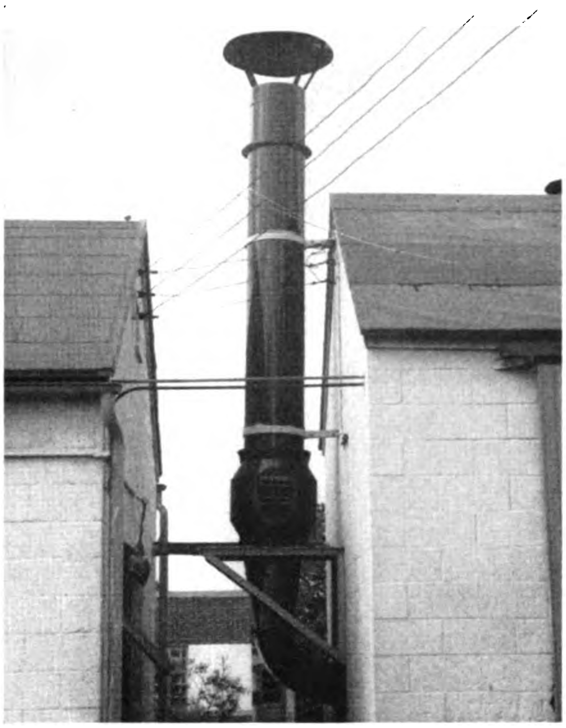


FIG. 2.4.13: Type I polyvinyl chloride discharge stack

of 2000°F. Thus, high factors of safety must be applied and long-term rather than short-term strength values must be used for design purposes. It is also important to avoid sudden changes of cross-section areas by the use of gradual tapers or adequate fillets. Special care must be taken to assure alignment of sections of ducts. Adequate allowance for expansion must be made and all duct work must be supported properly.

Construction based on conservative design is expensive but more economical than under-designed structures. Since German engineers recognized the need for proper design, they were able to erect plastic structures which have given over 15 years of service in the German chemical industry. While plastic duct work based on American materials has not been used as long as the German product, there is every reason to believe that properly designed plastic duct work will be just as satisfactory in this country. Manufacturers who have insisted on high factors of safety already can supply case histories on units with up to five years of service.

A safety factor of at least four, based on tensile or flexural strength at the maximum operating temperature, should be used in all standard design work. Provisions for expansion with temperature should be made. Obviously, the design engineer must know the maximum anticipated operating temperature for each system under consideration.

Adequate allowance for thermal expansion must be made in all systems through the use of compressible gaskets or expansion joints. Expansion joints have been fabricated using sleeves of plasticized polyvinyl chloride sheet to connect sections of rigid plastics.

Proper support for duct work is just as important as correct design. Horizontal structures of unplasticized polyvinyl chloride and styrene rubber plastic duct work should be supported at intervals not greater than 25 feet. Ring supports should be placed within six inches on each side of every mating flange. Vertical sections of polyethylene duct work should be supported at least every five feet and preferably continuously. Plastic duct work should be installed as a free member throughout its entire length.

Consideration should be given to the design of structures to provide smooth liquid flow. Transition and transformation pieces should be 12 inches in length for every one-inch change in inside diameter. Whenever possible, 90-degree and 45-degree elbows should be used with a throat radius equal to the diameter of the duct.

Bolts of at least three-eights-inch in diameter should be used to join all flanges, the number of bolts for each flange being equal to the number of inches of inside diameter of the duct work. Care should be taken to prevent excessive stress from the bolts in these flanges by using torque wrenches. Insofar as possible, the use of guy wires for vertical structures should follow standard practices used for steel structures. It is recommended that free-fitting plasticized polyvinyl chloride rings, at least four inches in width, be placed around rigid plastic duct work before fastening the split metal clamp for attaching guy wires.

It should be remembered that plastic duct work is much lighter than a comparable steel structure and, hence, less support is needed. For example, a 100-foot-tall 12-inch unplasticized polyvinyl chloride duct will weigh approximately 300 pounds while a comparable steel duct will weigh almost a ton. In present practice, vertical rigid plastic stacks are supported every 35 feet. However, plastic stacks over 100 feet high have operated successfully in Germany using only top and center guy supports.

The diameter of discharge stacks should be enlarged gradually in order to produce a slight decrease in resistance with length. Since smooth flow is obtained much more readily in plastic duct work, there are fewer problems with plastics than with metal exhaust systems (Figure 2.4.13).

The physical and chemical properties of typical materials used for the construction of duct work are given in Tables III and IV. Obviously, some of these properties will vary with different formulations and fabrication methods. However, these data should serve as a useful guide whenever plastic products are considered. (Tables III and IV, pages 87 and 88.)

Listed below are service data of successful installations in this country and Europe. These should convince the most skeptical potential user that plastic duct work should be considered whenever corrosive services are involved.

SERVICE DATA ON PLASTIC DUCT WORK INSTALLATIONS

Type of Plastic	*Chemical Service*	*(A)*
Polyethylene	Sulfuric Acid	
	Exhaust duct system	4
Polyvinyl Chloride	Sulfuric Acid	
	24-inch duct work	2
	36-inch duct work at 180°F.	2
	Exhaust hood and duct system at 160°F.	2½
Polyvinyl Chloride	Sulfuric Acid	
	Exhaust ventilators for gas, 12,000 cu. meters/min.	7
	Duct work in sulfuric acid production unit	15
	Piping duct work and ventilating fans in sulfuric acid production plant	15
Polyvinyl Chloride	Hydrofluoric Acid	
	Etching system	2
Polyvinyl Chloride	Hydrofluoric Acid	
	3-foot diameter duct work, 100 feet long	1
	Textile industry, 300-foot duct work	1
	Duct work	4
	Duct work	3
	Pharmaceutical chemical manufacture duct work	6
	Organic dye manufacture duct work	6
Polyvinyl Chloride	Hydrochloric Acid	
	20-inch duct, 300 feet long	10
Polyvinyl Chloride	Nitric Acid	
	Exhaust ventilators for gas, 12,000 cu. meters/min.	7
	100 feet—3-foot diameter duct work, nitric acid production plant	1½
Polyvinyl Chloride	Hydrofluoric-Nitric Acid	
	23-foot hood and 24-inch duct work	2
	Chemical plant exhaust fans	1
	Steel duct work and plating process	3
	Hoods and 16-inch duct work for pickling process	2
	Electroplating hoods and exhaust systems for 84 plating tanks	1½
	Fume exhaust system for anodizing and electroplating process	2
	Hood and exhaust system	5
Polyvinyl Chloride	Aluminum Chloride	
	1-foot diameter duct work, 120 feet high outdoors	10
Polyvinyl Chloride	Organic Polyisocyanate	
	Duct work	1
Polyvinyl Chloride	Chlorine	
	Duct work	2
Reinforced Flame Resistant Polyesters	Chlorine	
	Duct work	1
Reinforced Polyesters	Chemical laboratory hood and duct work	2

(A) Number of years of satisfactory service.

CONCLUSION

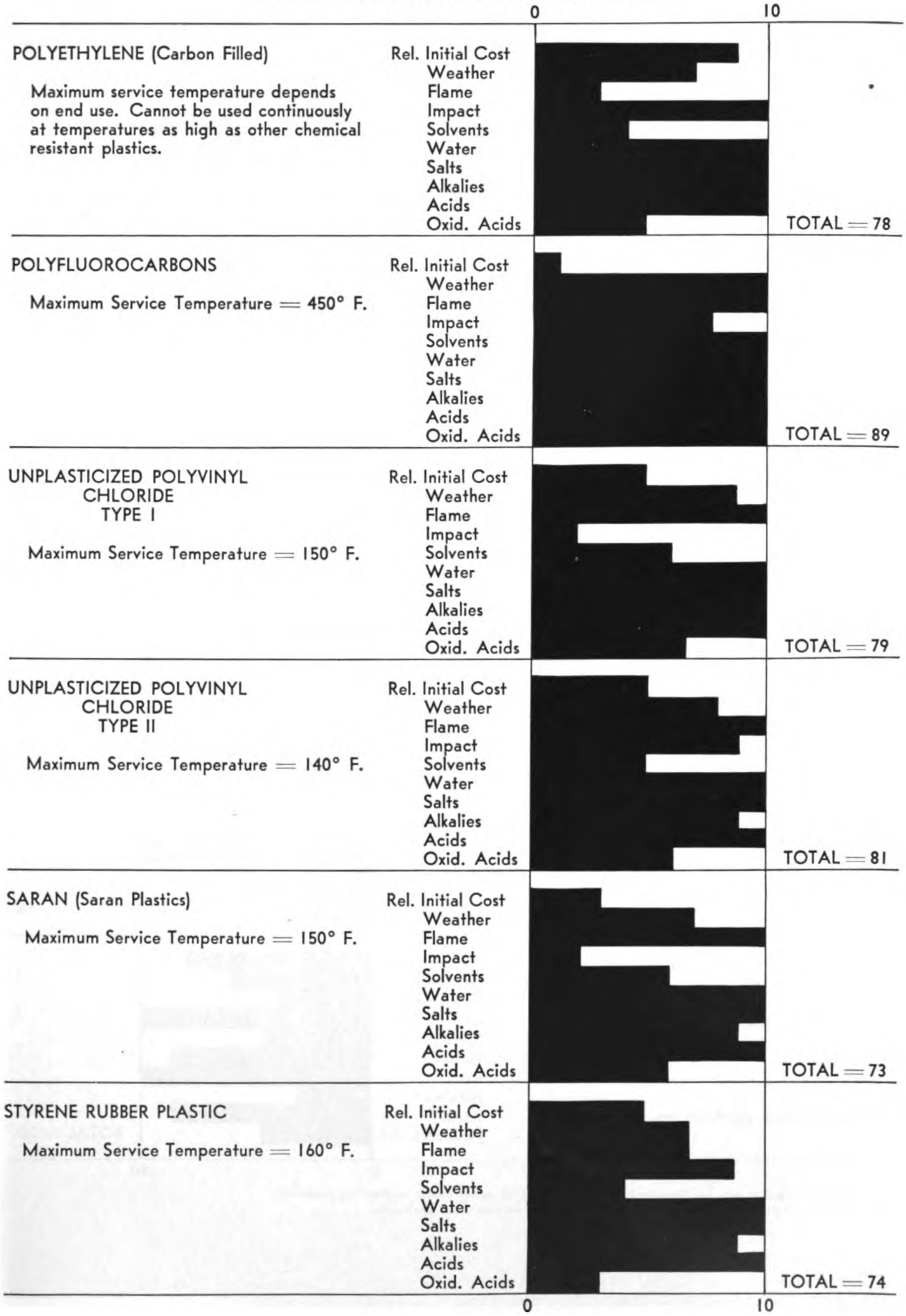
In spite of the desirable properties and the simplicity of the design of the duct work discussed, it must be emphasized that plastics cannot be expected to replace all other types of materials used for such applications. Plastics must simply be considered as another standard material of construction.

Obviously, when resistance to corrosion, good flow-characteristics and light weight are required, few materials can compete with plastics in the construction of duct work operating at temperatures below 150°F. Plastics should not be thought of as either a substitute product or a panacea to solve all problems. However, when properly selected, designed, fabricated and installed, they will often out-perform all other available materials of construction.

TRADE NAMES

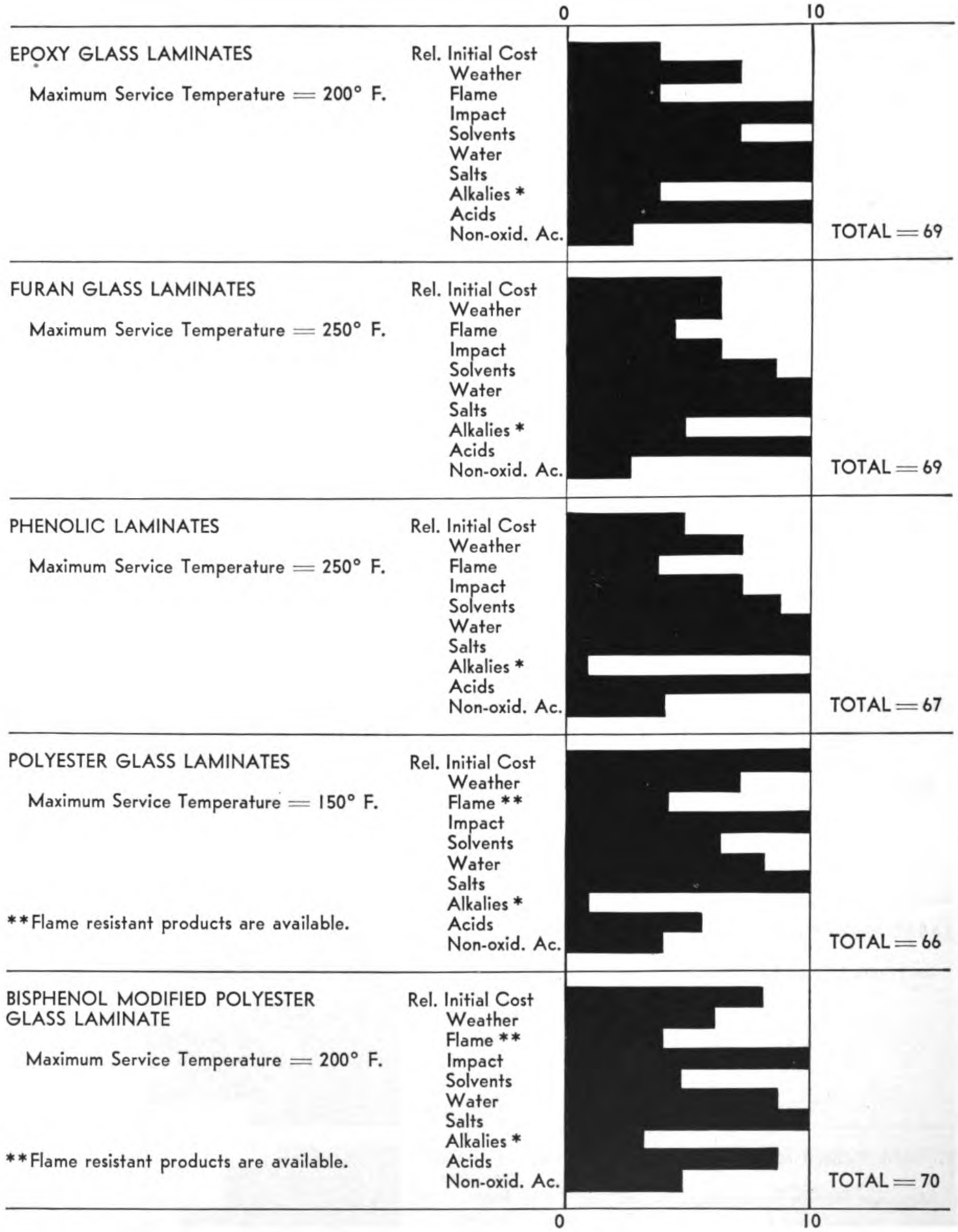
TRADE NAME	MANUFACTURER	ADDRESS
POLYETHYLENE, CARBON-FILLED		
Agiline A	American Agile Corp.	Cleveland, O.
Agiline B	American Agile Corp.	Cleveland, O.
Agiline CP	American Agile Corp.	Cleveland, O.
Atlas Polyethylene	Atlas Mineral Products Co.	Mertztown, Pa.
UNPLASTICIZED POLYVINYL CHLORIDE, NORMAL IMPACT, TYPE I		
Agilide	American Agile Corp.	Cleveland, O.
Ampcoflex	Atlas Mineral Products Co.	Mertztown, Pa.
Boltaron	Bolta Co.	Lawrence, Mass.
Lucoflex	American Lucoflex Co.	New York, N. Y.
Quexon	Quelcor, Inc.	Philadelphia, Pa.
Rigidon	Heil Process Co.	Cleveland, O.
Seilon 5800	Seiberling Rubber Co.	Akron, O.
Vyflex	Kaykor Industries	Yardley, N. J.
UNPLASTICIZED POLYVINYL CHLORIDE, HIGH IMPACT, TYPE II		
Pee Vee Cee	Atlas Mineral Products Co.	Mertztown, Pa.
Vancor 2	Colonial Plastics Mfg. Co.	Cleveland, O.
SARAN, SARAN PLASTICS		
Saran	Dow Chemical Co.	Midland, Mich.
STYRENE RUBBER PLASTICS		
Ampcolite	Atlas Mineral Products Co.	Mertztown, Pa.
Uscolite	U.S. Rubber Co.	Passaic, N. J.
EPOXY GLASS LAMINATES		
FURAN GLASS LAMINATES		
Haveg 60	Haveg Corp.	Newark, Del.
PHENOLIC LAMINATES		
Haveg 41	Haveg Corp.	Newark, Del.
POLYESTER GLASS LAMINATES		
Agilide	American Agile Co.	Cleveland, O.
Plastaloy	Atlas Mineral Products Co.	Mertztown, Pa.
Pla-Tank	Chemical Corp.	Springfield, Mass.
FLUORINATED ETHYLENE RESINS		
Fluroflex, Teflon, Kel-F	Resistoflex Corp.	Belleville, N. J.
Fluorothene	Bakelite Div., Union Carbide & Carbon Corp.	New York, N. Y.
Kel-F	M. W. Kellogg Co.	Jersey City, N. J.
Teflon	E. I. du Pont de Nemours & Co., Inc.	Wilmington, Del.

TABLE I — PROPERTIES OF THERMOPLASTICS



Relative index values are rated from 0 - 10 with 10 being the most desirable.

TABLE II — PROPERTIES OF THERMOSETTING PLASTICS



*** Resistance to alkalies can be improved through the use of other fabric reinforcing materials.
Relative index values are rated from 0 - 10 with 10 being the most desirable.**

TABLE III

PHYSICAL PROPERTIES OF TYPICAL PLASTIC STRUCTURAL MATERIALS

Kind of Material	Tensile Strength 77°F. (psi)	Compressive Strength 77°F. (psi)	Flexural Strength 77°F. (psi)	Flexural Modulus 77°F. (psi)	Impact Strength, Izod ft.lb./in. notch	Thermal Conductivity b.t.u./sec./sq.ft. °F./in./10^{-5}	Thermal Expansion in./in./°F x 10^{-5}	Heat Distortion °F, 264 psi Fiber Stress	Specific Heat b.t.u./lb./°F	Specific Gravity
Polyethylene	1400	—	1700	—	high	8	10	—	0.55	0.92
Styrene Rubber Plastic	4500	10000	8000	3 x 10^5	10	2.0	3.4	185	0.35	1.06
Polyvinyl Chloride Type I	8500	11000	14000	4.5 x 10^5	0.8	3.7	4	165	0.25	1.40
Polyvinyl Chloride Type II	5800	8000	1000	3.5 x 10^5	12	4.5	6	155	0.25	1.40
Epoxy[a] Glass Laminates	50000	60000	70000	2.5 x 10^6	20	—	5	250	—	1.8
Phenolic[b] Laminates	23000	30000	25000	1.5 x 10^6	10	4	2	300	0.25	1.6
Polyester[c] Glass Laminates	40000	50000	50000	2 x 10^6	20	5	—	450	0.25	1.8
ASTM Test Method	D638	D695	D650	D650	D256	—	D696	D686	—	D792

a: Glass cloth impregnated with liquid epoxy resin. Cured with an aromatic diamine at 200°F.

b: Glass cloth impregnated with liquid phenolic resin. Heat cured under pressure.

c: Glass cloth imprgenated with liquid polyester-styrene blend.
Cured with benzoyl peroxide at 200°F.

TABLE IV

CHEMICAL RESISTANCE

Ratings:
- E—No attack.
- G—Appreciably no attack.
- F—Some attack but usable in some instances.
- P—Attacked—Not recommended.
- N—Badly attacked.

	Poly-ethylene		Styrene-Rubber Plastic		Polyvinyl Chloride Type I		Polyvinyl Chloride Type II		Epoxy Glass Laminates		Phenolic Laminates		Polyester Glass Laminates		Bisphenol Modified Polyester Glass Laminates	
Acids	75–125°F		75–160°F		75–160°F		75–150°F		75–200°F		75–200°F		75–150°F		75–200°F	
Acetic, 10%	E	E	E	G	E	G	E	G	E	E	E	E	E	E	E	E
Acetic, glacial	P	N	N	N	G	N	F	N	N	N	E	G	N	N	E	F
Benzene sulfonic, 10%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Benzoic	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Boric	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Butyric, 100%	N	N	N	N	F	N	N	N	G	F	E	E	G	N	G	F
Chloroacetic, 10%	P	N	N	N	E	G	G	F	E	E	E	E	E	F	E	E
Chromic, 5%	E	E	E	N	E	E	E	E	F	N	G	P	G	N	G	P
Chromic, 50%	E	E	F	N	E	G	G	P	N	N	F	N	F	N	F	P
Citric	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Fatty Acids (higher than C_6)	F	P	G	F	E	P	G	P	G	F	E	E	G	F	E	E
Fluosilicic	E	E	E	E	E	E	E	E	N	N	N	N	N	N	N	N
Formic, 90%	G	F	N	N	E	P	G	P	G	F	E	E	G	N	E	F
Hydrobromic	E	E	E	F	E	E	E	E	E	E	E	E	G	F	E	G
Hydrochloric	E	E	E	F	E	E	E	E	E	E	E	E	G	F	E	G
Hydrocyanic	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Hydrofluoric	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Hypochlorous	E	E	E	F	E	E	E	G	P	N	F	N	G	F	G	F
Lactic	E	E	E	F	E	E	E	E	E	E	E	E	E	E	E	E
Maleic, 25%	E	E	E	E	G	F	G	F	E	E	E	E	E	E	E	E
Nitric, 5%	E	E	G	N	E	E	E	E	F	N	G	P	G	P	E	F
Nitric, 20%	E	E	F	N	E	E	E	G	N	N	N	N	N	N	F	N
Nitric, 40%	E	G	N	N	E	G	F	P	N	N	N	N	N	N	N	N
Oleic	P	N	E	F	E	F	G	P	E	G	E	E	G	F	E	E
Oxalic	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Perchloric	E	E	E	F	E	E	E	E	E	E	E	E	G	F	E	G
Phosphoric	E	E	E	F	E	E	E	E	E	E	E	E	G	F	E	G
Picric	E	G	E	E	P	N	P	N	E	E	E	E	E	E	E	E
Stearic	P	N	E	F	E	G	G	P	E	E	E	E	G	F	E	E
Sulfuric, 50%	E	E	E	E	E	E	E	E	E	E	E	E	G	F	E	G
Sulfuric, 70%	E	F	G	N	E	E	E	F	F	N	E	P	F	P	G	P
Sulfuric, 93%	F	N	N	N	E	F	P	N	N	N	G	N	N	N	F	N
Oleum	P	N	N	N	F	P	N	N	N	N	P	N	N	N	N	N
Mixed Acids, 57% H_2SO_4; 28% HNO_3	E	N	N	N	E	G	G	F	N	N	N	N	N	N	N	N
Alkalies																
Ammonium Hydroxide	E	E	E	F	E	E	E	E	F	P	P	N	F	N	G	F
Calcium Hydroxide	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Potassium Hydroxide	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Sodium Hydroxide	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N

Acid Salts																
Alum or aluminum sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Ammonium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Copper chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Ferric chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Nickel chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Stannic, chloride	E	E	E	E	E	E	E	E	E	P	E	E	E	F	E	G
Zinc chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Alkaline Salts																
Barium sulfide	E	E	E	G	E	E	E	E	G	F	P	N	G	P	G	F
Sodium bicarbonate	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Sodium carbonate	E	E	E	E	E	E	E	E	E	E	E	N	G	P	E	E
Sodium sulfide	E	E	E	G	E	E	E	E	G	F	P	N	G	P	G	F
Trisodium phosphate	E	E	E	G	E	E	E	E	G	F	G	N	G	P	G	F
Neutral Salts																
Calcium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Magnesium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Potassium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Sodium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Gases																
Chlorine, dry	P	N	E	F	E	E	E	G	G	F	F	N	G	F	G	F
Chlorine, wet	N	N	E	N	E	G	G	F	F	N	P	N	P	N	F	N
Sulfur dioxide, dry	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Sulfur dioxide, wet	E	E	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Organic Materials																
Acetone	P	N	N	N	N	N	N	N	E	P	E	E	N	N	N	N
Alcohol, methyl, ethyl	E	P	E	P	E	G	E	F	E	E	E	E	E	F	E	G
Aniline	N	N	N	N	N	N	N	N	F	N	F	P	P	N	P	N
Benzene	N	N	N	N	P	N	N	N	E	P	E	E	F	N	G	N
Carbon tetrachloride	N	N	N	N	N	N	N	N	E	F	E	E	E	N	E	F
Chloroform	N	N	N	N	N	N	N	N	E	F	E	E	G	N	E	F
Ethyl acetate	N	N	N	N	N	N	N	N	E	G	E	E	P	N	G	P
Ethylene chloride	N	N	N	N	N	N	N	N	E	F	E	E	F	N	G	F
Formaldehyde, 37%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Phenol, 5%	E	G	G	F	E	G	E	F	E	F	E	E	G	N	G	F
Trichloroethylene	N	N	N	N	N	N	N	N	E	F	E	E	N	N	F	N
Papermill Applications																
Kraft liquor	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Black liquor	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Green liquor	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
White liquor	E	E	E	F	E	E	E	E	N	N	N	N	N	N	N	N
Sulfite liquor	E	E	E	F	E	E	E	E	E	E	E	E	E	G	E	E
Chlorite bleach	E	P	E	P	E	G	G	F	P	N	F	P	E	N	E	F
Alum	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Chlorine dioxide	F	N	N	N	E	E	G	F	P	N	N	N	E	G	E	E

	Poly-ethylene		Styrene-Rubber Plastic		Polyvinyl Chloride Type I		Polyvinyl Chloride Type II		Epoxy Glass Laminates		Phenolic Laminates		Polyester Glass Laminates		Bisphenol Modified Polyester Glass Laminates	
Acids	75–125°F		75–160°F		75–160°F		75–150°F		75–200°F		75–200°F		75–150°F		75–200°F	
Photographic Industry																
Developers	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
General Use	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Silver nitrate	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Fertilizer Industry																
General Use	E	E	E	F	E	E	E	E	E	E	E	E	E	E	E	E
Steel Industry																
Sulfuric acid pickling	E	G	E	E	E	E	E	E	E	E	E	E	G	F	E	E
Hydrochloric acid pickling	E	G	E	E	E	E	E	E	E	E	E	E	G	F	E	E
H_2SO_4-HNO_3 acid pickling	E	F	N	N	E	E	E	F	P	N	F	N	N	N	F	P
Textile Industry																
General Use	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Food Industry																
General Use	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Breweries	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Dairies	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Miscellaneous Industries																
Plating	E	F	E	G	E	E	E	G	E	E	E	E	E	G	E	E
Petroleum	P	N	E	E	E	E	E	E	E	E	E	E	E	G	E	E
Tanning	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Oil and Soap	F	N	E	F	E	E	E	G	E	E	F	F	G	F	E	E
Water and Sewer	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

GENERAL DISCUSSION

MR. HUNTZICKER: I thank you, Dr. Seymour, for your very interesting talk and moving pictures.

The discussion part of this program is going to be handled by Mr. Joseph W. Kreuttner, who is a member of the Board of Governors of Building Research Institute, and is Vice President and Director of Buensod-Stacey, Inc., New York City, an air conditioning and engineering firm. He is a graduate of Columbia University, has a rich experience in air conditioning and refrigeration. He is a member of the American Society of Heating and Air-Conditioning Engineers. We turn this part of the program over to Mr. Kreuttner, knowing it will be in good hands. Mr. Kreuttner.

MR. KREUTTNER: The use of plastics as given in Dr. Seymour's paper applies specifically to protection against corrosive fumes and the action of acids and other corrosive chemicals in the air stream. Air conditioning has a very important part in the industrial field and especially in the chemical field. But the greater part of the use of duct work is in commercial installations—banks, office buildings, hotels and hospitals—where corrosive action isn't necessarily the most important consideration, although it does have some bearing in the selection of materials.

We necessarily have to keep the cost of air conditioning and ventilation systems down. But, as Mr. Berkson pointed out yesterday, you don't compare the cost per square foot of materials; you compare the installed cost with the results and then make your dollar comparison. It doesn't make any difference what material is used, provided you get a better result in the end.

In the case of a chemical factory, an exhaust system which may be conparatively small can be a continuing cost if it does not stand up. If the corrosive films eat it out once a year, you have to replace it once a year. Even if you have to pay 10 times as much to put in a plastic system of duct work, the over-all result is much cheaper.

Dr. Seymour's paper deals mostly with exhaust systems of a magnitude of pressure up to about 20 pounds per square inch. In air conditioning we don't have any such pressures. Our pressures are very rarely in excess of two or three ounces per square inch. Therefore, the strength of the material isn't as important as the durability, the cost of installation, the cost of fabrication and the stiffness of the material.

Now, let's have some questions.

MR. I. W. MENDELSOHN (Department of Interior): I would like to ask Dr. Seymour if he can give some representative comparative costs between plastic installations and competitive materials—covering original cost of installation, maintenance, life, and particular uses of the materials.

DR. SEYMOUR: The best that I can do is to give you approximate costs for duct systems of the type that are being designed and used today in plastics, and then give you American experience and European experience.

Today, quarter-inch duct work, of various sizes from six inches up, generally costs from $3.50 to $5 a square foot for the original installation, and that is expensive. This type of material has been giving very good service in the United States for the last four years. These same types of materials have been used for 20 years in Germany and are still being used. Men who have examined those structures today can't find any change in them from the time they were installed.

It would be quite difficult to extrapolate and say how long American installations will last. We feel if they last for three or four months, they are going to last a long time. Perhaps that $3.50 to $5 a square foot is too expensive for what you are considering, but the plastics industry has sort of backed into this field by taking the most difficult cases first.

In time, it will be possible to reduce the safety factor required in the structure as we acquire confidence based on experience. We don't want to put out shoddy materials and have them fall apart and have people say they are no good. We can gradually cut down on plastic safety and lower the cost.

MR. KREUTTNER: I would like to comment just a minute on Mr. Mendelsohn's question. The rayon industry has a severe problem with corrosive fumes. Approximately 30 years ago, studies were made and it was decided that the original cost was of very little consequence because the application was such that the plant must run continuously. It was impossible to stop it. Therefore, in evaluating the cost of duct work used to protect a process, the original cost may be of small consequence.

MR. E. N. SQUIRE (E. I. du Pont de Nemours): My question is referred to Mr. Kreuttner. Concerning the need for a flexible duct for modern air-conditioning systems; what is the diameter of that flexible duct?

MR. KREUTTNER: I don't know what it should be. I know that so far we have used several different types of flexible conduits in air-conditioning systems. One manufacturer has used at least five different types. One type is all metal made very like an oversized BX cable. It's poor because the very nature of it leaves an overlapping surface which must move; therefore, although there is only one- or two-thousands of an inch clearance, there is a leak point.

Another type, used in recent years, is made of a combination of metal and plastic-coated fiberglas. A third type is made with the spiral helix on the inside and covered with a coated fabric to make it airtight, and a fourth type is another form of the BX cable with, I believe, an asbestos fiber filler between these moving edges to reduce the leakage. That, again, has not been too satisfactory. But the general use of small, flexible conduits is growing, and I think that in the building industry—and that is what we are here for, primarily—the plastics development should be aimed at things like that. It's part of the building.

There is another reason for flexible conduits, and that is interference with other mechanical parts of the building—electrical conduits, electric lighting fixtures. The air-conditioning system is usually the last thing that goes in, and it has to snake around other conduits. In order to do that, a flexible conduit is of great importance.

MR. E. E. GRUBER (General Tire and Rubber Company): In connection with flexible ducts, I would like to know whether or not there has been any reclassification or qualification as to fire resistance, fire retardment and combustibility.

MR. KREUTTNER: I think there is another section of the program which deals with standards and codes, and I imagine that that would be one of the factors to be discussed there. Certainly, fire resistance or fire repugnance is important. The next question?

MR. GEORGE D. MEIER (Haskelite Manufacturing Corporation): I would like to ask Dr. Seymour if he could expand his discussion with regard to the type of plastics used in air ducts with acid atmospheres and whether reinforcing was used, or whether it was all the same plastic materials.

DR. SEYMOUR: Just about every plastic that I named has been used, and they have been selected on the basis of a knowledge of properties and good designs. Fiberglas-reinforced plastics have already been mentioned. They have been used satisfactorily to some extent. Sometimes they failed when the resin was not properly selected, when it was not acid resistant or alkaline resistant, as the case may be.

The materials that have been used most in such applications are polyvinyl chloride, acrylonitrile blends, and polyethylene, in that order. The greatest amount of experience has been with rigid polyvinyl chloride type. That is the material that has been used successfully in Germany for 20 years and in this country for four years. The acrylonitrile blends have been used almost that long.

One of the drawbacks of those materials is that they cannot be cemented. Polyethylene has been used to a moderate degree, because it is flexible and can go around corners, but it requires support. It will resist most acids, alkalies, and corrosive salts, but is not very good for solvents.

MR. KREUTTNER: There is time for one more question.

MR. WALT KUCHTA (Pace Corporation): In a slide, Dr. Seymour, you showed fiberglas-reinforced duct work around a collapsible mandrel. Would it be possible in that case to leave paper tubes in your application, or wrap around a paper bag core and leave it in your final assembly, as we do in the plastics tooling industry for bracing up dies and fixtures?

DR. SEYMOUR: That is certainly possible and practical, and it has been done. It worked out quite well, and it depends upon the final usage of the duct work. If you are willing to let the paper just get wet and come out gradually, it would work all right. There has been a tendency to remove the cardboard or paper by water afterwards—it is considered an expendable mandrel—but it is a technique which could be used to advantage.

Part III

STANDARDS AND CODES FOR PLASTICS IN BUILDING

STANDARDS FOR PLASTIC PRODUCTS

By Gordon M. Kline*
National Bureau of Standards

PLASTICS are relatively new materials of construction. They are therefore, in an awkward position with respect to standardization. The building engineer —who is familiar with well-established standards in the fields of metal, concrete, and wood—wants similar technical specifications for plastics. However, the plastics engineer is generally still directing his attention to the development of new markets and to the modification and combination of his raw materials to produce improved products for those markets.

One frequently hears the statement that plastics are too complex and too subject to change at this time to lend themselves to standardization. This is taking a very narrow view of the function of standardization. In addition to the well-known static type of standard—the purpose of which is to provide quantitative and reproducible measures of well-defined masses or constants—there is the dynamic type of standard which serves as a yardstick of quality in a diverse and changing system. The ever-higher "standard of living" in this country, to which plastics are making a material contribution, is an example of one such dynamic standard.

Dynamic standards are greatly needed, and highly beneficial, in the utilization of a new material in engineering applications where the durability and performance of conventional materials are well established. These dynamic standards provide a medium in which the collective judgment and experience of engineers—representing producers and consumers, and including architects and builders—can be set forth for the guidance of both groups in the further development and utilization of a new material in a specific application.

The very process of drafting the standard often serves to reveal critical areas of ignorance in which further investigations must be concentrated in order to promote proper and efficient use of the material.

PUBLISHED STANDARDS

What is the present state of the development of standards for plastics suitable for use in the building industry? Actually, only a small beginning has been made. Various subcomittees have been organized by Committee D-20 on Plastics of the American Society for Testing Materials, and by The Society of the Plastics Industry, Inc., to work on specifications for products for use in this field. Examples are the polyvinyl chloride plastic pipes and reinforced plastics made with polyester resins and glass fibers and fabrics.[1]

The SPI also has sponsored investigations at Battelle Memorial Institute and the National Sanitation Foundation (headquartered at the University of Michigan's School of Public Health) to develop information on the properties of plastic pipes suitable for plumbing purposes, and it has groups working on the preparation of standards for plastic lighting fixtures, and foamed plastics.

A chemical firm has sponsored research at the Massachusetts Institute of Technology's School of Architecture on the use of plastics in building construction.

The National Electrical Manufacturers Association[2] and ASTM Committee D-20 on Plastics[3] have published specifications for decorative laminated plastics which are extensively used for wall paneling, window trim, and the like, in public buildings, hotels, and restaurants.

Commercial standards for polystyrene wall tile and for colors—for plastics for use in kitchen and bathroom accessories—have been prepared by industry committees sponsored by SPI and the Manufacturing Chemists' Association, Inc., and published by the U. S. Department of Commerce.[4] The Asphalt Tile Institute has issued a specification for plastic floor tile.[5] The British Standards Institution also has published a number of standards covering plastic products used by the building industry.

The Department of the Air Force and the Navy Bureau of Aeronautics have contributed to the development of standards of interest to the building industry by their early and effective work on the preparation of specifications for reinforced plastics and the raw materials entering into their manufacture. Their work on specifications and utilization of transparent

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plastics has, likewise, been a contributing factor to the promising development in the use of these materials in industrial glazing.[7]

NBS WORK ON STANDARDS FOR PLASTICS

The National Bureau of Standards, in addition to maintaining the basic standards applicable to all the physical sciences and striving constantly to improve the accuracy and precision of such measurements, also has, as one of its statutory functions, the job of providing assistance to industry in the formation of standards for products used in commerce and by government.

The NBS Plastics Section has participated actively in the preparation of these dynamic standards by the development of methods for determining the properties of plastics, by the determination and publication of technical data relating to many types of plastics, and by the assignment of personnel to work on technical committees engaged in the drafting of standards for plastics.

These committees have included those of the American Society for Testing Materials, the American Standards Association, International Standardization Organization, and The Society of the Plastics Industry, Inc., as well as various government committees.[8]

The NBS Plastics Section is now cooperating with the various industry and technical society committees working on standards for plastics for the building industry. The pioneering efforts of these groups should lead to faster and surer progress in the application of plastics in the building industry.

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BUILDING CODE REGULATION OF PLASTIC BUILDING MATERIALS

By Frederick J. Rarig*

Rohm & Haas Company

BUILDING code regulations represent one of the most potent exercises of the police power extant in the jurisprudence of modern government. The exercise of this power over the $40-billion building industry can conceivably guide the building industry in the creation of idyllic communities blessed with all the benefits of modern technology and the products of our society's most creative artists and artisans.

On the other hand, the misuse of this power can frustrate science, kill research, drive creative artists mad, and produce drab, uninspired and unpleasant places in which to live and work. It can produce conflicts between industry and labor and jurisdictional controversies within labor itself. It can encourage industries which should be discouraged, and stunt the development of new products and new industries which should be encouraged and brought to full fruition.

Traditionally, building codes have been the product of metropolitan and municipal legislatures. Within our generation, *state* building codes have developed; and with the advent of suburbia, *county* building codes and *metropolitan area* building codes are becoming commonplace.

Because the owners of buildings frequently have nationwide building programs, because architects work on a national basis, because material suppliers supply a national market and, for that matter, because individual contractors build in every part of the country, there has been developing during the past 30 years an insistent demand for uniformity in the building code field.

The Building Officials Conference of America with its Basic Code, the Pacific Coast Building Officials Conference with its Uniform Code, the Southern Building Congress with its Southern Building Code, the American Standards Association with its Building Standards, the National Board of Fire Underwriters with its National Building Code, the Underwriters' Laboratories with its Re-examination Service and its uniform method of evaluating building materials from a fire hazard point of view, and the National Bureau of Standards, cooperating with trade associations and professional societies, have all worked diligently to satisfy this demand for uniformity of requirements and uniformity of test procedures.

The problem of overlapping enforcement agencies and multifarious standards for materials and construction becomes more serious to all of us as the jurisdiction of the building officials at various levels of government is extended to include approval of specific material and the licensing of fabricators and producers of building materials.

The evaluation and approval of specific building materials and the inspection and regulation of their source of supply is an outgrowth of the tendency in building code legislation to move from materials specifications codes to codes based on performance standards. A performance criterion, it is recognized, is not much better than the integrity of the producer of the material or the fabricator of the assembly.

In developing factory inspection and plant licensing requirements, building officials are taking a leaf out of the experiences and practices of Underwriters' Laboratories labeling service. The possibility here of inconsistency of administrative determinations, duplicate license fees, and aggravating annoyances practically surpasses one's imagination. How we can prevent duplication and the creation of hopeless confusion is not a subject which we can explore today, but I should like to suggest that it is a subject which should receive our attention in the months ahead.

I would like to discuss briefly the approach the plastics industry has taken to the problem of legislative recognition of plastics under state, county and municipal building codes.

My own company was brought into the building field by architects and designers who dreamed up uses of our materials which never occurred to the chemists who invented them and, as you might expect, architects' drawings were our letters of introduction to building inspectors.

I will never forget my introduction to a plans reviewer in the Building Department of the City of New York. An architect was proposing to use a resilient, shatterproof, plastic material as a substitute for glass

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in partitions and glazing and in stairway barriers in redecorating an old mansion for a child-care center. The proposed use of the plastic would have eliminated large quantities of dark mahogany finish and trim materials and produced a light and airy atmosphere—all without exposing the children to the possible hazard of broken glass.

When the architect's request for a building permit was denied, I cheerfully undertook to ascertain the basis of the denial. The Building Department employee dismissed my question, "Why was the material rejected?" with a single sentence which was both a question and a denunciation. He said, "It's plastic, ain't it?" and elaborated by pointing out that I could read the entire Administrative Code of the City of New York and not find the word "plastic" anywhere in the code. This was conclusive, as far as he was concerned, and I was sent on my way to ponder the problem of how to get the word "plastic" into the Administrative Code of the City of New York.

Shortly thereafter our company received an inquiry from the School Board of the City of New York asking whether or not certain biometrics data developed by the Air Surgeon General's Office on the basis of a wartime use of one of our plastic materials would be applicable to debris set in motion by the shock wave created by the explosion of an atomic bomb. The school board had received some adverse publicity because the corridors which it designated as air-raid shelter areas were, in part, lighted by transom-type windows which borrowed light from the classrooms. The caustic comments of refugee children who had experienced numerous air raids during World War II did not flatter these air raid shelters. The school board was seeking a substitute for the window glass that lined its corridors.

We had to tell the school board that we had only fragmentary data on the behavior of our materials under conditions of atomic explosion, but we had rather conclusive information to the effect that the material could not be used within the City of New York because the Administrative Code did not provide for its use. In response they hinted, but did not state, that they might be able to get the necessary approvals if we would supply relevant data establishing the safety of our material under conditions of atomic explosion and, incidentally, quote them an acceptable price.

To make a long story short, we developed conclusive evidence of the safety not only of our particular plastic material but also of numerous other plastic materials under conditions of atomic explosion and established that the use of these materials could virtually eliminate the shattering hazard created by the presence of glass in shelter areas and in other areas where personnel is expected to remain in the event of an air-raid alert or actual air raid.

The experience with the Building Department in New York was repeated in many cities throughout the United States and we realized that, wherever it was proposed to use plastics for light-transmitting purposes, we were up against old-fashioned specification codes. There simply was no performance standard for light-transmitting materials. The art and the industry had known only one light-transmitting material for hundreds of years and the building codes uniformly reflected the assumption that this was the only practical light-transmitting material. It was up to us to develop a broader approach to this problem of light transmission.

At the outset we were met by the fact that most plastic materials suitable for light transmission are combustible within the meaning of most building code definitions of the term. We had to convince the building officials that there was a public interest to be served in permitting the limited use of new light-transmitting materials for glazing and other uses. These materials are lightweight, resilient, and non-shattering—materials which eliminate the shattering hazard of glass and reduce substantially the weight of many, many types of installations where glass would ordinarily be used—but are materials which unlike glass, do present a fire problem.

It was not difficult to convince the building officials that there was a public interest in having a lightweight, resilient material available as a light-transmitting medium. The problem soon became that of developing principles by which the safe plastic materials (safe from a fire point of view) could be separated from the unsafe, and the use of these materials limited to an extent consistent with fire safety while at the same time giving the public the advantage of a reduction in weight and in shattering hazard.

When we first broached to building officials the subject of possible amendments to building codes to permit and regulate the use of plastics in buildings, we were asked to define what we were talking about; and we were quickly told that regulatory agencies would not approve legislation permitting only one type or class of plastic. On the other hand, we were also quickly told that no one would accept general legislation which would open the gates to a flood of non-standardized, experimental products. The problem was to define the new field of plastics in meaningful, practical terms.

It was obvious that established industries, such as the cement industry and the paint industry, would not appreciate a definition of plastics which would subject them to requirements governing these new-fangled modern plastics—the product of the chemical industry. Furthermore, the plastics industry would not be pleased with a definition which would freeze regulations around existing materials.

After reviewing precedents in the regulatory field, we concluded that the problem of defining plastics was closely analogous to the problem of defining drugs in establishing pure food and drug regulations. The pure food and drug laws define a drug as a product listed in the U.S. pharmacopoeia. We had to find an authoritative list of plastics, of the type with which we are concerned, which would be accepted by regulatory officials. We concluded that the publication "Technical Data on Plastics" of the Manufacturing Chemists' Association, Inc., which is kept up to date by the association's technical committees, was a worthy equivalent in our field of the pharmacopoeia in the drug field. We, therefore, defined the subject of our legislation as "plastic materials made wholly or principally from standardized plastics listed and described in the current edition of 'Technical Data on Plastics' published by the Manufacturing Chemists' Association, Inc."

Having defined the subject, we were asked by the building officials how we proposed to classify plastics according to their fire hazard. We turned to the basic classification of plastics according to their fire hazard published by the National Board of Fire Underwriters in its Research Report No. 1—"Fire Hazards of the Plastics Industry" and we developed standards of classification based on ASTM test procedures which eliminate rapid-burning plastics and classify slow-burning and self-extinguishing plastic material.

Next, we were asked how we proposed to enable a building inspector to tell a sheep from a goat if he did not happen to have readily available an analytical laboratory capable of analyzing the exact composition of complicated organic compounds. To answer this, we proposed a requirement that each plastic material offered for sale in the building field must be submitted to the building official for approval, properly identified and described in terms of pertinent data on burning characteristics, products of combustion, weatherability, chemical properties, etc. We also required that every piece or container of plastic to be delivered at the building site be identified with the approved identification which would be the same as that used in submitting the material for approval, and of course also the same as the symbol used in the Certificate of Approval and the Building Permit. This would enable the building inspector to assure himself that the data applicable to the material approved was equally applicable to the material actually installed—in other words, that they are the same material.

Our proposed legislation does not legislate any material into the market. It is "enabling legislation" which permits the building official to approve standardized plastics for specific uses and sets up basic limitations on these uses. These limits fix maximum areas and minimum burning-rate standards for light-transmitting uses of plastic materials. These restrictions are analogous to those governing interior finishes, but not identical. Plastics for light-transmitting purposes could not be blanketed in under existing interior trim and finish regulations because the installations for light-transmitting purposes preclude placing the material against opaque surfaces.

Code proposals based on this approach to the problem of plastic regulations have been approved by the Building Officials Conference of America and the National Board of Fire Underwriters and by such cities as Los Angeles, New York and Milwaukee. Similar proposals are being considered by regulatory agencies in San Francisco, Seattle, Boston, Detroit, Minneapolis, St. Paul, etc.

A good example of the legislative approach in action is the regulation adopted by the Fire Marshal of the State of California to govern the use of plastic domes in skylights. We readily acknowledged that the use of a combustible material in skylights should be limited in area and the units should be distributed on a roof in such a way as to avoid congestion which makes movement on the roof difficult. These considerations were reflected in a requirement that the area enclosed by a single unit should not exceed 50 square feet and the total area of the roof occupied by such units should not exceed 15 per cent of the floor area of the room or occupancy covered by the roof on which they are installed.

It was also recognized that burning brands might possibly ignite a combustible material employed in a skylight. Therefore, design specifications were established which would insure that no burning brand would adhere to the surface of the material or lodge against the edge of the material. This was accomplished by setting up pitch requirements and by providing that the dome should be located at least 8 inches above the plane of the roof and that the edge of the material should be protected by metal. Finally, it was provided that such domes should not be located over fire exits if they were the sole means of egress in the event of fire.

Another good example of the type of regulation which reconciles the "hazard created" with the "hazard eliminated" by the use of plastics, is that governing luminous ceilings. A precedent in this field which we hope will be followed is established by the requirements of the National Board of Fire Underwriters. Their proposed regulation provides that plastic luminous ceilings shall be subject to the regulations governing interior trim and finish unless it is established by recognized laboratory tests that the plastic panels employed in the ceiling will fall out of their mountings at temperatures well below their ignition temperatures. The theory and the fact here is that such low heat distortion materials present no flame-spread problem and they also create no concealed air space hazard because long before the high temperatures develop which create fire storms, the material is shriveled up and deposited on the floor contributing rather slightly to the total BTU's available in the furnishings of the occupancy.

Beacuse of the possibility of falling panels creating a panic hazard, our proposed legislation in this field would rule out such installations from public assembly areas and from corridors and exit areas and, of course, also from high hazard occupancies. This type of restriction drastically reduces the market for these installations but it does not have the effect of denying the public the benefits of the superlative light which this kind of installation provides in occupancies where such light is desirable and where its availability is definitely in the public interest. Common installations are classrooms, public utility control rooms, libraries, banks, etc.

This, then, in general, is the pattern which we in the plastics industry have worked out with regulatory officials. We have accepted the performance requirements traditionally imposed on materials offered for conventional interior trim, finish, and structural uses when our materials are so employed; but, in the light-transmitting field, where most of the materials offered cannot, because of their structure, be accurately evaluated in conventional testing equipment, we have asked that ASTM standards be used to eliminate undesirable materials and to classify those which are acceptable; then, we have accepted area limitations and design specifications on the use of the materials thus accepted and classified. We strongly recommend to regulatory authorities that this statutory formula for the control of our materials be incorporated in a separate provision of the building code to which architects, builders, and material suppliers can turn for guidance in the event that they propose the use of a plastic material in a light-transmitting function.

Where performance standards are already generally applicable—such as in the fields of plumbing, insulation, sheathing, and structural members—we have not proposed any new legislation. Here, at the moment at least, the plastic industries' primary problem seems to be one of standards.

I should point out that within the building field we have drawn heavily on the precedent which we established earlier in the field of outdoor signs and display structures. We have been successful both in the United States and in Canada in achieving legislative recognition of plastic materials for use in the letters, decorations and facings of virtually every type of sign, both illuminated and nonilluminated. Thus, approved plastics can be used in projecting signs, wall signs, marquee signs, roof signs and ground signs. This latter category includes, of course, both pole signs and the traditional bulletin board of spectacular.

I do not mean to suggest that our statutory program in the field of buildings is as firmly established as that in the sign field. In a field as dynamic as the building field, products as varied and inherently as dynamic at the field itself—such as plastics seem to be—must move forward tentatively and in a spirit of experimentation consistent with the ever-changing pattern of the industry itself but always, of course, within conservative limitations established by reference to traditional standards of public safety.

Despite the comparatively few actual adoptions of code amendments explicitly providing for the use of plastics, the industry has, in recent years, obtained numerous temporary approvals on an administrative basis for the use of plastic materials in lighting fixtures, skylights, glazing of unprotected openings, transparent roof and wall panels in Type IV and V buildings, luminous ceilings in nonassembly and nonhazardous occupancies, and interior partitions in other than institutional occupancies.

Our work on code provisions through the Manufacturing Chemists' Association and The Society of the Plastics Industry, Inc., is actually an attempt to formalize on a uniform basis the pattern of approval established by the administrative acceptances issued by forward-looking building officials who have been willing to exercise their administrative discretion in the interest of a fair chance for a new and promising building material.

This explains why it is possible in many cities to use plastic materials for light-transmitting purposes on at least a limited basis, despite the absence of code provisions expressly providing for such uses.

The insurance industry has, for the most part, accepted these materials on substantially the same basis as the building officials. Their experience is being formalized also in official amendments to such codes as the National Building Code. This amendment, which will become effective we understand in November (1954) will define good practice in the use of plastics for the guidance of rating bureaus throughout the United States.

If the regulatory program providing for the use of plastics in buildings has not kept pace with commercial aspirations and the public demand, it is because in the final analysis the regulatory pattern can only be established after the building industry has defined the problem by its demand for the use of the material.

GENERAL DISCUSSION

MR. HUNTZICKER: Thank you, Dr. Kline. The discussion part of this program will be moderated by Mr. Paul E. Baseler, who is Executive Secretary of Building Officials Conference of America. He is a graduate of Washington University. For many years he was employed in St. Louis architectural firms and later entered private practice as an architect. In 1947 he was Building Commissioner for the city of Jennings, Missouri. In 1950, he moved to Columbus, Ohio and became Code Coordinator of the Building Code for Ohio and helped to draft the new Ohio State Building Code. Mr. Baseler.

MR. BASELER: Thank you, Mr. Chairman. I should like to start this discussion period with a very brief statement in regard to building codes in general and their background. Building codes in general are concerned with safety; first, with life safety and health safety, then structural safety and fire safety—safety which will protect the people occupying the building from the hazards inherent to occupancy and will afford safe escape in the event of such hazards. Building codes are, of course, also concerned with the matter of protection between buildings, so that one building does not become an undue hazard to its neighbors.

In this conference we are dealing with a new material, one which has started out—and I trust I will be forgiven for the reference—as a "substitute born of necessity resulting from the shortage of tried and proven materials." In its development this material has evidenced properties that differ from the heretofore known materials, but we have been unable as yet to measure the extent of these differences and we cannot calculate them by formula or criteria used to evaluate other materials.

Traditionally, the development of building regulations has been based almost entirely on long periods of experience. The concept of requirements based on laboratory tests and technical evaluations is comparatively new. Unfortunately, this concept has not been accepted to date by all local authorities. I stress "local authorities" because building codes are enforced at the local level, not at some high level. The concept is, however, rapidly gaining recognition.

Consequently, in the field of our subject we have two strikes against us before we step up to the plate: The lack of experience to back up the product and the lack of uniform procedure for acceptance of new products.

Almost every material used in buildings has faced these same two problems. Many, if not most, materials with which we are familiar have weathered the first and have long since established sufficient useage to establish their acceptance, at least in familiar forms and methods of use. In this respect I believe we can safely say that we are in a much better shape today than we were when these tried and proven materials passed muster.

Today each city, village or hamlet is developing its building regulations. We have four model building codes, sponsored by as many organizations, which have received national recognition and have been widely accepted. At least three of these organizations have much in common. Working through them, it should be much easier to obtain recognition and establish rational regulations to govern a new material once standards can be developed to control the hazardous properties of the material. I believe the four code writers have recognized the desirability of getting away from the concept that performance criteria can be only established by 50 years of experience.

Now, I should like to open this period for questions, reminding you to identify yourself and your organization.

MR. JOHN K. HONISH (The Bakelite Company): Mr. Baseler, I am shocked to hear you say that you were of the impression that plastics were born of a need for substitutes. We believe most materials—whether they be plastics, or the invention and development of new alloy steels, or the improvement of rubber, or even the development of a new species of wool, or whatever materials for construction that we might think of—are the result of the creative inventiveness and a general desire to add to our fund of knowledge and technology, and I hope that will be a part of the thinking that goes into this symposium. We have new materials that are to be explored, evaluated and re-emphasized. We are trying to establish engineering principles so these new materials may be used properly, so there will be no continuation of people running head-on into things and making improper use of them and creating unsatisfactory relationships between people who are investing their money in the industry and in the buildings that are a part of our general economy. I wonder if you wouldn't have another look at your introductory remarks. (Applause.)

MR. BASELER: You direct your statement to my remarks. May I say that in stating that the use of plastics originated in the construction field as a substitute, I thought that was brought out in previous discussions. I did not mean to imply—perhaps my remarks were too brief—that I think for a minute that they are substitutes. They are not. (Applause.) . . . Yes?

MR. S. H. INGBERG (Structural Fire Protection Engineer): I am not in the plastics field, except from the standpoint of the relation of plastics to a fire hazard, with which I have been concerned for some time. I have prepared a brief discussion on this matter, Code Regulation of Plastics, which through the courtesy of the Institute and Dr. Huntzicker will be included with the proceedings of this conference.[1]

Briefly, we (fire protection people) are concerned with the properties of plastics from the standpoint of their ignition temperature, heating, and combustion, and flame spread. The American Society for Testing Materials has developed some tests for flammability, but when we come to the mass extent, continuity of plastics as they are applied to buildings, these tests give only qualitative information.

MR. BASELER: We have gotten away from the question concept here a bit.

MR. JAMES ARKIN (Architectural Consultant): I would like to address this question to Mr. Rarig. I wonder if he could tell us a little about the proposed use of plastic for the roof on the Guckenheim Museum in New York City that was designed by Frank Lloyd Wright. What was the final result of this case by the New York City Board of Appeals?

MR. RARIG: I am sorry that I don't know what the final decision is. Under the regulations, it would require a special permit from the New York City Board of Appeals to permit its use, and I don't know what the status of that hearing is. I know that Mr. Wright has had at least one conference with the Board, but I have not been told what the result was.

MR. DAVID RUBENSTEIN (Chem-Stress Structures Company): Mr. Rarig, have you any knowledge of the acceptance of reinforced fiberglas in any building code in places where steel is commonly used as a structural wall-bearing material, either alone or as reinforced concrete or in combination with steel as a multistructural material? And, if you have, how long would it take the building code people to give us a code?

MR. RARIG: I don't know of any code which would explicitly, in so many words, permit this material in a structural member, although it is obvious that the conventional use of reinforced polyester sheet in light steel buildings is in part structural. As for predicting how long it would take regulatory officials to do anything, I would not venture into that realm of speculation. One might say, I suppose, that one could develop a built-up section that would perform equally with an accepted material. Many, many building codes permit the substitution of a new material for an established material if you can demonstrate equivalent performance. So you might, on a case-by-case basis, very well get a wall section or honeycomb section approved, but there is no legislative program at the moment which provides for that eventuality.

MR. B. L. WOOD (American Iron and Steel Institute): Mr. Moderator, I have a suggestion, rather than a question. In the meeting yesterday, and today on several occasions, temperatures were discussed in the order of 1700 degrees. I think it might be helpful to this audience if an explanation were made of the difference between flame-spread requirements and fire resistance. They are two different animals, depending on the use of the material, and it might be helpful if that explanation were made.

MR. RARIG: Well, as I understand it, fire-resistance rating is a rating that addresses itself to the problem of preventing fire from moving from one occupancy into another, or through a roof, a wall, a door, or through a window. Flame spread is concerned with the spread of fire quickly through an occupancy by means of the ignition of the surface materials, which may not involve any substantial burning of the member itself. As I understand it, the hazard there is that flame will spread very quickly over the surface of materials, exhausting the available supply of oxygen and resulting in death by asphyxiation. In layman's language, I think that is an approach to it, and, of course, the tunnel test is an almost, I think, universally recognized technique for evaluating flame spread of finishes and triple materials. There are established tests that involve one-hour, two-hour, three-hour and four-hour resistances to evaluate the fire resistance of protected metals and unprotected metals and laminates, and so forth.

MR. BASELER: Dr. Kline, would you like to add anything to that from the standpoint of your study in standards?

DR. KLINE: Well, I was thinking that both the aircraft industry and the one that I have had recent experience with (the shipbuilding industry) have, to some extent, shown the way for further acceptance of these materials in the type of building construction which we are discussing here.

MR. RARIG: Some of the work that they have done was on combustion of plastic materials, which was very important from the standpoint of the inhabitants of the occupancy.

MISS GRAYBOFF (Architectural Forum): This is a question with subquestions. If the answer is no to the first one, there is no need to go on. The question is addressed to Mr. Rarig, and then if the answer is yes, I'd like to direct a few questions to Dr. Kline.

Can we conclude from your talks that plastics, per se, will be accepted most easily into those areas having performance codes over those having specification codes, and if so, wouldn't it seem that the best way to promote plastics in building and construction would be to promote performance codes? If the answer is yes, I have some more questions; if it is no, I am finished.

MR. RARIG: It certainly is a good way, and we

1. See Page 134.

have both the trade associations and individual companies who have devoted a great deal of time and some money to supporting the development of performance codes.

MISS GRAYBOFF: Then, here are the subquestions: Has any count been taken of the number of performance codes now in effect, and if so, what is their percentage as compared with specification codes, and what percentage of the population do they cover? Can you name two major cities that have adopted such codes, and is there any single group, governmental or building industry group, now actively promoting performance codes?

MR. RARIG: I have sort of cut the ground out from under both you and myself. Actually, this concept of a performance code really states an objective rather more than it states a reality. I think most of the people in this audience know very well that you cannot get away from the effect of design on safety, and you can't get away from some other basic characteristics of a structure. You can't, in other words, embrace entirely this concept of performance, and I wouldn't say that there is a single building code that is purely a performance code. There just isn't such an animal. It's a matter of degree, somewhat like the distinctions in the field of psychology between extroversion and introversion. Few people are either all of one and none of the other, and vice versa, and that's the case with building codes.

MR. BASELER: I should like to toss the ball directly back to you by saying that you are touching on a question of statistics here, a matter in which your publication could probably do considerably more, lend considerably more assistance than it has in the past. Perhaps it would be well for you to undertake a survey to find out those statistics, and we would all be very happy.

MISS GRAYBOFF: We might have it in our files. I just wanted it brought out.

MR. RARIG: You'd have an awfully hard time drawing up statistics that meant a lot. Just in our little bit of an experiment some of the codes that pride themselves in being performance codes provided throughout that glass should be used . . . and you offer a substitute—forgive me.

MR. BASELER: We have time for one more question.

MR. W. D. BARLOW (Staff, Office of Naval Material): I have a question for Dr. Kline. In plastic materials, is the toxic effect being considered? We are particularly interested in food preparation and food service equipment in plastic material.

DR. KLINE: The question of toxicity of plastics is being worked on more particularly by the Public Health Service, National Institute of Health, and certain recommendations have already been issued by that agency with respect to the acceptability of certain of the plastic materials and plasticizers for use in applications where foods or beverages are concerned.

I would like to add one comment on the question from the young lady as to performance codes and specifications. I am a firm believer myself that a mistake is made in trying to cover, let us say, in one code all plastic pipe without identifying to some extent the particular type of pipe that you are talking about. I think that this matter of special standards and codes is all part of a necessary pattern. We must have our specifications, let's say, for the PVC pipe, our standards for the PVC pipes, our specifications and standards for polyethylene pipe. The application of these materials, let us say, in the building industry should certainly not be restricted by the particular specification of one of these materials. The application should be left, I think, to the performance type, but the use of that material, or of any plastic material, will certainly be expedited by a good quality standard which the architect and the builder can use in an area which is essentially ignorant of the chemistry of the material.

Part IV

FUTURE USES OF PLASTICS IN BUILDING

THE FUTURE OF PLASTICS IN BUILDING

By Johan A. Bjorksten*

Bjorksten Research Laboratories, Inc.

WE HAVE heard, in detail and most interestingly, about a large number of applications of plastics in building; some decorative, others related to floors, windows, curtains, and to secondary structures of many kinds. However, in looking to the future of building I believe that we should envisage the use of plastics in primary structures—that we might reverse the title of this talk and talk not about Plastics in Building but about Building in Plastics.

The chief advantages that plastics offer in primary structures are a high strength-to-weight ratio, translucency when desired, continuity of structure, and fire resistance. I make a point of fire resistance very deliberately because the Hetron endochloro polyesters, when glass reinforced, give the highest mechanical properties obtainable today with any fire-resistant plastic (Figure 4.1). I understand that once volume has been attained these fire-resistant-type polyesters may be manufactured at a price comparable to any of the other conventional polyesters.

To illustrate applicability of mass-production techniques to building elements, I am going to show you two pictures supposedly taken in the year 7000 by an archeologist who has been excavating the ruins of what was once Chicago. Figure 4.2 shows an injection molding machine used around the year 2000 for making wall sections (for housing) in high-impact polystyrenes and stabilized vinyls. Figure 4.3 shows a traffic tunnel built by continuous extrusion of a glass-reinforced polyethylene, subsequently cross-linked by radiation, as the archeologist might have found it in the year 7000.

We see here examples of techniques which lend themselves to minimizing labor costs; to building structures at costs which will be low once the volume justifies the necessary machinery. In the meanwhile, polyesters have an advantage in low equipment cost, and the trend is strongly in favor of fire-resistant materials now that they are available at a rapidly decreasing cost. I believe in the future of fire-resistant plastics such as the Hetron polyesters, polyvinyl chlorides and melamines, particularly for roof, duct, partition and similar internal structures.

Regarding ways of using plastics, much is to be said for the honeycomb structure, where plastic-impregnated paper provides an inner insulating core of high strength. Figure 4.4 shows polyurethane foamed-in-place type sandwiches between plastic sheet walls. This construction gives a rigid plastic panel of high thermal insulating properties. The cost is still too high to compete in standard applications, although special situations economically justify such uses even now. For example, it is often not feasible to add a second story to a building whose original foundation was designed for one story only, because the foundation will not support the additional weight without impractically expensive alterations. In such situations it may even now be economically practical to add the second story in plastic construction, which gives the space needed at a fraction of the weight required for steel, brick or even wood.

Weight strength comparison is shown in Figure 4.5 between concrete, wood, steel and glass-reinforced Hetron fire-resistant polyester. I took this plastic as the point of comparison, because it is the strongest of the fire-resistant plastics, as far as I know.

A beam 20 feet long, laterally supported, able to support an 800 pound/foot static load, will weigh: in concrete, 4180 pounds; in wood, 644 pounds; in steel, 500 pounds; and in glass-reinforced Endochloro type polyester (Hetron) 60 per cent glass cloth, 127 pounds. The deflection of the plastic beam, however, exceeds the usual standard of 1/290 of the span. If the deflection is to be kept within this limit, the weight of the plastics beam would be 355 pounds. However, the required rigidity may be attained by special design adapted to plastic so that the strength properties can be fully utilized. The ease with which plastic beams may be handled reduces on-site building costs and should make possible great simplification in structure, as Figure 4.6 indicates.

So far, we have been concerned with more or less conventional above-ground construction, but in this atomic era we should give some thought to the advantages of underground construction. These include low exterior finishing and low heating costs, as well

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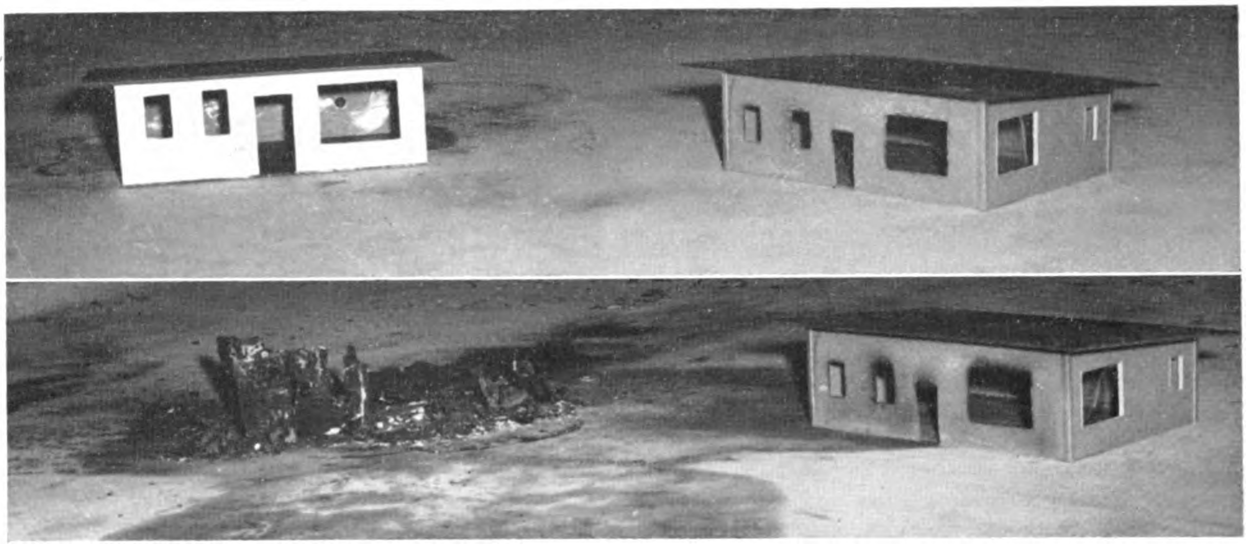

FIG. 4.1: Model house at right is constructed of Hetron glass reinforced flame resistant plastic; one on left is wood. Top illustration is before burning; bottom after soaking with gasoline and igniting.

as construction ideal for the use of the heat pump which eliminates the need for fuels.

Although most people associate underground construction with thoughts of leaky, moist basements, there is no reason today why underground construction should be any less attractive than above-ground construction. Air conditioning and modern waterproofing are part of the answer. In modern waterproofing the plastic film plays a great part which I think will continue to increase. The waterproofing compounds, whether silicones, tung oil compounds, microcrystalline wax compounds, or plain asphalts, all have the disadvantage that if the wall or the floor cracks then the crack also occurs in the waterproofing.

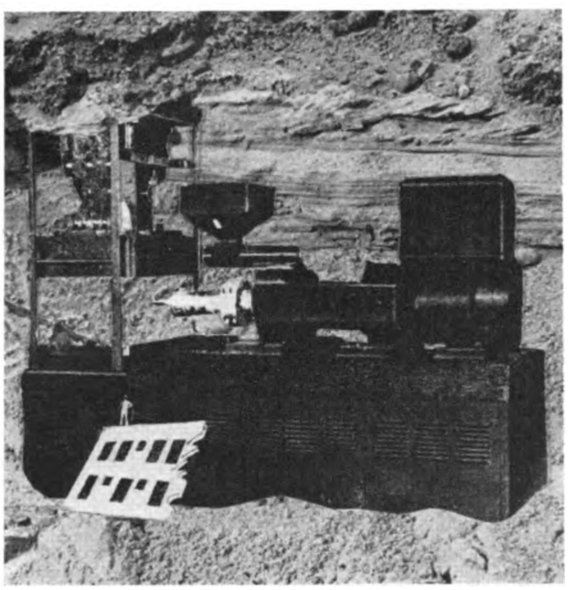

FIG. 4.2: Excavated ruins (year 7000). Injection molding machine.

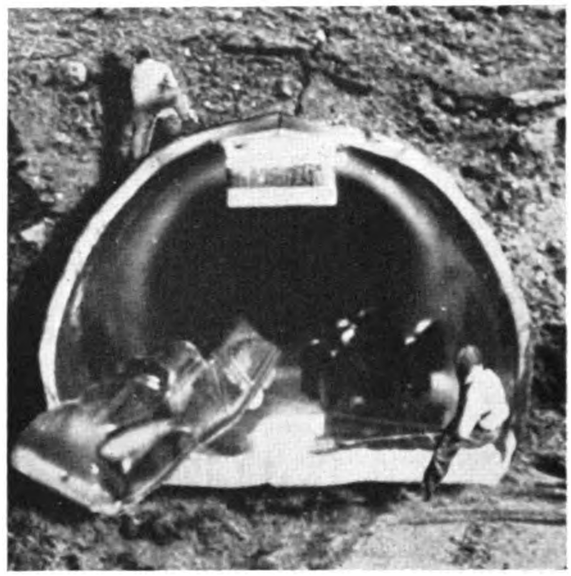

FIG. 4.3: Excavated ruins (year 7000). Traffic tunnel made of extruded reinforced irradiated polyethylene.

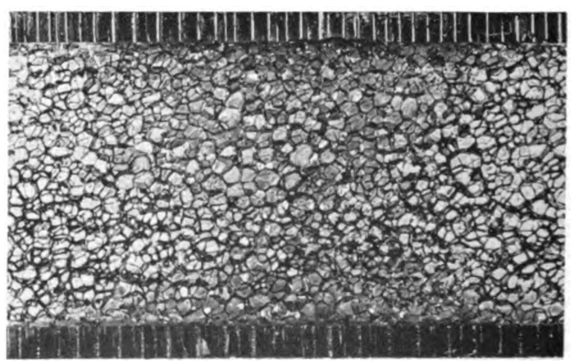

FIG. 4.4: Structural wall section, insulating foam between rigid plastic skin.

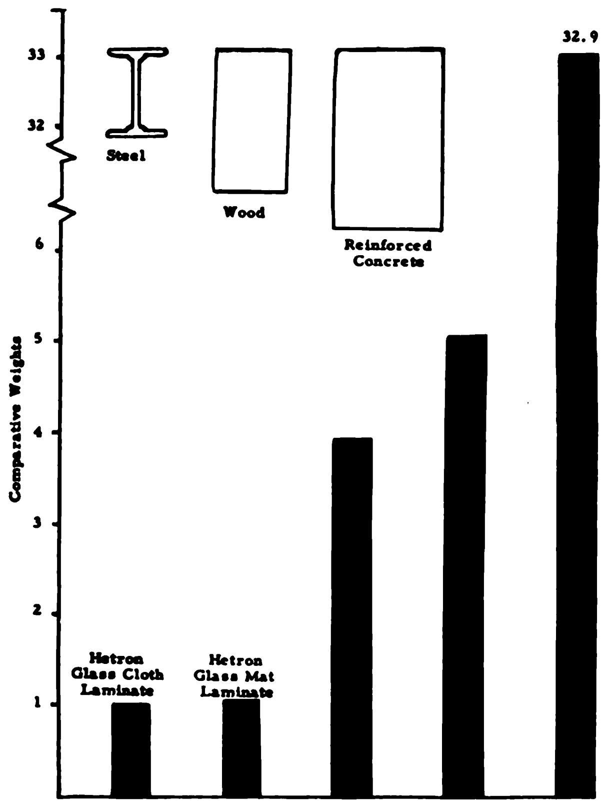

FIG. 4.5: Weight ratios of structural beams of equal strength, but neglecting deflection.

FIG. 4.6: Plastic beams are light weight

This is not true of plastic films. When a stretchable plastic film is built into a floor or wall and the floor or wall cracks, then the plastic film will stretch and will still prevent water from coming through that crack. A suitable plastic film should stand up practically forever in a wall where it is protected both from excessive temperatures, from light and from very much air circulation.

In Figure 4.7, you see a 95 per cent underground house which we are building. It is in the side of the ridge so that the large picture windows look out through the side of the hill, but the other walls and the roof are covered by soil. Building costs are estimated to be less than those of an equivalent structure above ground, and maintenance and heating costs far less. A structure of this nature would have been dif-

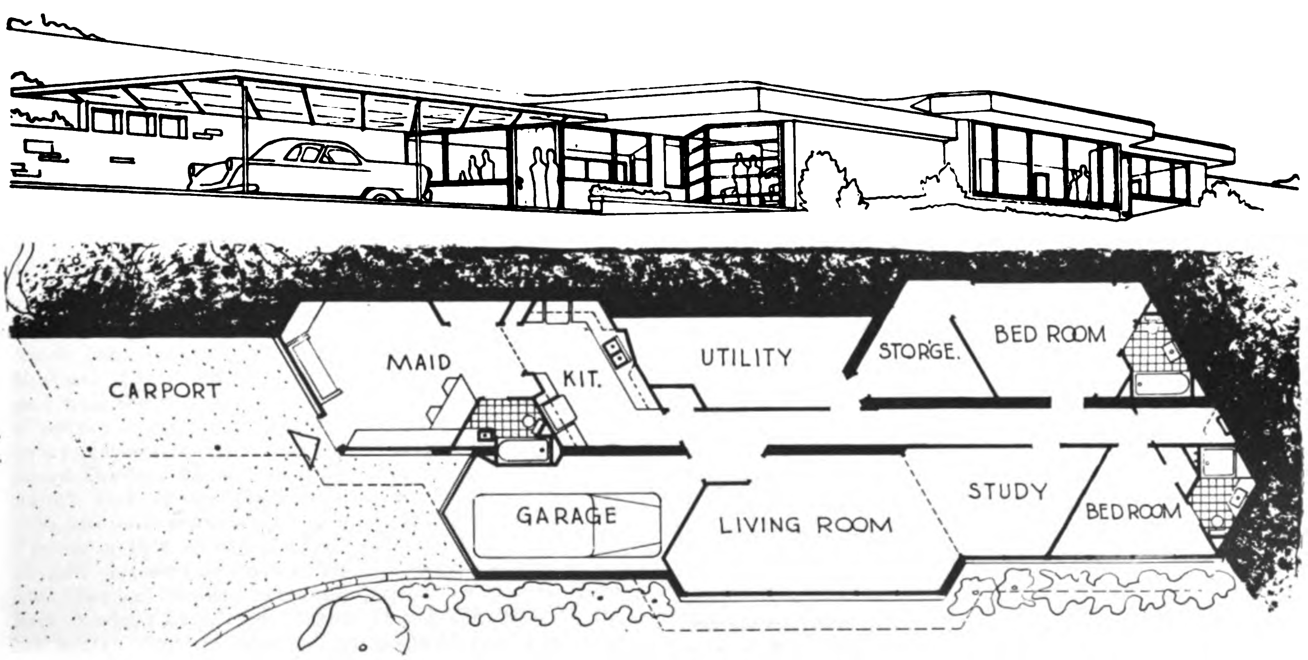

FIG. 4.7: Drawing of underground home and floor plan

FIG. 4.8: Floating plastic dwellings

ficult or undesirable a few years ago but today, thanks to the advances in plastic technology and in air conditioning, we anticipate no difficulties.

When I was asked to talk on this occasion, it was suggested that we should not hesitate to dream boldly about the future. I shall use this privilege.

As we all know, the increase in population of the world is much more rapid than the increase in food production. In a few generations the population will begin to exert so strong a pressure that humanity will have but three choices: rigid birth control in all countries; an atomic war sufficienty intense to wipe out at least half of the earth's population; or to commence agriculture over the vast areas that are now the oceans.

Almost 500 miles to each side of the equator extends a marine area which is practically perpetually calm, where the sun shines almost every day, and the temperature is a pretty steady 86 degrees the year around. The development of extreme high-strength plastic films make it possible to utilize this immense belt for agricultural purposes. The Department of Interior has sponsored work on plastic stills for converting salt water to fresh water. This fresh water could be used to cultivate plants under the protection of plastic films. Figure 4.8 shows some floating dwellings of plastics, probably of blown acrylic. Only the plastics, with their low cost in relation to the strength and ease of production on a large scale, would make it a practical engineering feat to utilize for agriculture these immense ocean plains. It will not be an easy task, but if it is a choice between this or starving, I do not doubt that humanity will take this path.

The area of ocean that might be cultivated in this way is about 23 million square miles, equalling the total arable land area of the world. A comparison of the areas, however, is not the whole story. The productivity of the plastic gardens on the equator is very much greater than that of comparable land areas because of ideal sun, humidity, and temperature conditions throughout the year. For instance, the Canary Islands, only 2,800 square miles, produce 70 per cent of all tomatoes consumed in Europe. From that, we may infer what 23 million square miles in these latitudes could produce.

When this development becomes reality, the diplomats and statesmen of the world will have a very busy time. So will, fortunately, the architects, builders and plastic engineers.

THE FUTURE OF PLASTICS IN BUILDING

A Round Table Discussion

Johan A. Bjorksten, Moderator

Panel Members (in the order of their presentations): Mr. Raymond Foster Boyer, Mr. Robert Fitch Smith, Mr. Dahlen K. Ritchey, Mr. James W. Fitzgibbon, Mr. George H. Clark, and Mr. Max Abramovitz.

DR. BJORKSTEN: We will now proceed with the round-table discussion. The first speaker is Mr. Raymond Foster Boyer, Director of Plastics Research for The Dow Chemical Company, who will talk about the responsibility of the research chemist in meeting the needs of the building industry. Dow Chemical, incidentally, is a member of the Building Research Institute. Mr. Boyer.

*MR. BOYER: Ladies and gentlemen, I think that plastics are of interest to you because of their inherent physical properties and because of the ease with which they can be fabricated into useful shapes. Due to these two factors, we already observe a number of types of applications of plastics in building, some of which have already been discussed.

However, a recurrent theme has been the limitations of existing plastics: first, the price of the base material compared with concrete, steel and wood; second, whether plastics can stand up under a continuous load at elevated, animated temperatures such as might be encountered in ordinary conditions—say around 200 degrees Fahrenheit—and what safety factor has to be brought into the design for load bearing; third is the question of how long plastics can withstand oxygen, ozone and ultraviolet light, either alone or in combination. Can they outlive the 20- to 40-year life of the bonds that were used to purchase the building as was asked yesterday; and, fourth, the question of fire resistance of the plastic materials.

There are some plastic materials which have one or more of these desired properties, but I don't think any one excels in all four. It seems to me that in the blue-sky future we need a plastic material as cheap as asphalt, with the temperature resistance and performance of the phenolics of nylon, with the wonderful outdoor aging characteristics of the reinforced plastics such as Saran or the endochloro methylene compounds that were just mentioned.

I think that until now the plastics research chemist has not had in mind these precise goals. Most of them have been thinking of a shorter time goal, one to five years. So this conference is presenting a new challenge. It seems to me that if the architects, designers, and builders can specify precisely what they want, performancewise, from plastic material, the plastics research chemists in universities and industry can eventually produce such materials.

Now for the price question, which is quite a bit different. The price of the basic plastic material is a technical economic problem that involves our whole economy—the price of coal, oil, and all of the other raw materials that go into plastics. I want to present some thinking on this question of price by means of a chart which shows a price in cents per cubic inch of material unit buying as a volume plotted against years. This cents-per-unit volume may be a little awkward. The price of wood shows at about a tenth of a cent per cubic inch. The black curve shows the price history for a fairly common, well-known thermoplastic material as buying grew in volume from a few thousand pounds per year up to several hundred million pounds per year. The price per cubic inch dropped about a factor of four.

We might add a dollars scale of maybe a $1.25 down to somewhere around 30 cents a pound. Then one might extrapolate and ask what the price would be if there were another 30-fold growth in the volume of that plastic. It appears that when the volume was up in the neighborhood of a few billion pounds per year, which is the sort of poundage that the builders might use, the price would not drop a great deal, a factor of another 30 per cent.

Right now, this base plastic is at a price of one

*Raymond Foster Boyer is the Director of the Physical Research Laboratory for The Dow Chemical Company, Midland, Michigan. He is a native of Denver, Colorado, and was graduated from the Case Institute of Technology, with a bachelor of science degree in physics, in 1933. He received a master's in physics from the same school in 1935 after which he joined The Dow Chemical Company as a student trainee. He started work in the firm's physical research laboratory in 1936, was made assistant director of the laboratory in 1945 and director in 1948. His field of specialization has been in the physical chemistry of plastics. He is a member of the American Chemical Society; American Physical Society; the New York Academy of Sciences; Sigma Xi and Tau Beta Pi. He has written numerous technical and scientific papers on plastics and authored various patents in the plastics field. He is 44 years old.

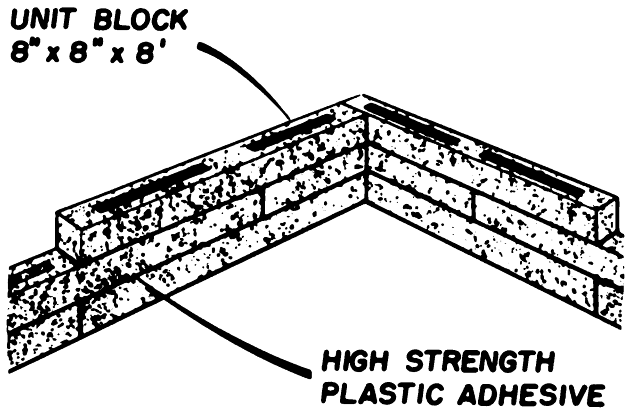

FIG. 4.9: Plastic foam blocks

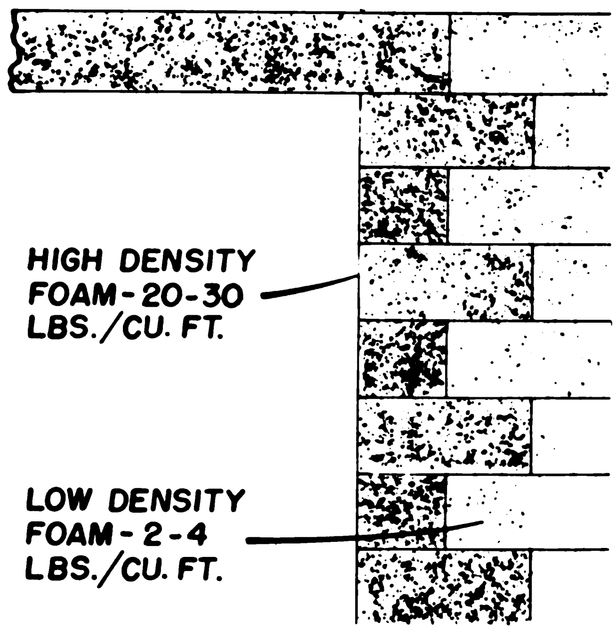

FIG. 4.10: Foam block lay-up at doors and windows

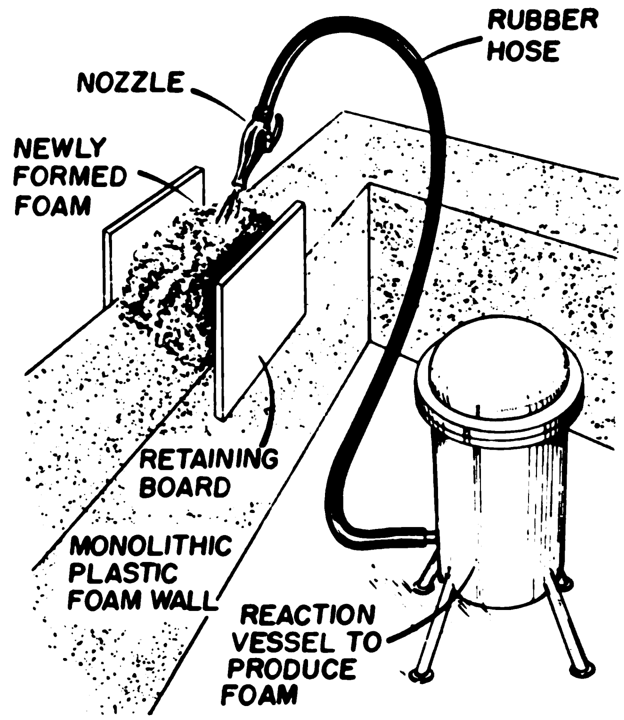

FIG. 4.11: Construction of foamed-in-place wall

cent per cubic inch. A foam of two pounds per cubic foot density has a schemed price slightly below wood, say nine-hundredths per cent of the price of wood. So you see that from solid plastic to foam plastic there is a tremendous jump in price.

This particular foam plastic does not have the compressive strength of wood, though it has thermal-insulation and rot-resistance properties. Foam material can be made in some intermediate range of density, say 20 pounds per cubic foot, where it would begin to equal the compressive strength of wood though, of course, its price would be higher. I think the general principle here is that no matter what happens to the price of the base polymer plastics, foam is still going to be five or ten times cheaper than the base plastic.

So it would seem that the price factor will determine the widespread use of foam, if it is to get into the structural elements of buildings. I have several slides illustrating various uses of foam plastics.

Figure 4.9 shows a foam block eight inches by eight inches by eight feet, weighing 8 pounds, as a building unit, foamed in place on the job. This material is low-density foam. The man who wants to do it himself can build an entire house with these blocks, laying them with a high-strength plastic adhesive. Figure 4.10 suggests something for a doorway. While the main wall material is low in density and compressive strength, around the door one would lay blocks of higher-density material, 20 to 30 pounds per cubic foot—toward the compressive strength of wood—which will stand impact and punishment.

Figure 4.11 illustrates the idea of building up a wall right on the site. Here is a sort of reaction vessel, and I'd like to have you think of it used as a concrete mixer is. One feeds into this vessel the plastic, some solvents and a catalyst and a plasticizer, and cooks it up and squirts it out through the hose. As the plastic mixture leaves the nozzle it foams up, and that foam eventually settles into its final rigid form. We just use forming boards and build up the wall.

This is quite visionary. I don't even know how to do it, so this is definitely "blue sky." But having built up that wall, I think we would go over it either with a high voltage X-ray machine or with a Cobalt 60 source and give it a dose of radiation to cross-link polymer the plastic material and try to improve its heat resistance and perhaps its tensile strength, and finally, I think it would be painted over, certainly coated over, on the inside with some water-based latex base paint or sand and other textured material to give a hard and textured finish. So this is a specific "blue-sky" idea.

In conclusion, I might sum up with three points:

If the architects and designers present a concrete and specific challenge to plastics research chemists, I think they can come through with the desired material; I think that economics is going to dictate the extensive use of foam plastics; and I think that in the future a lot of the plastic material is going to be formed right on the job, just as we now make concrete on the job. Thank you.

DR. BJORKSTEN: Thank you, Mr. Boyer, for this very interesting talk. I, personally, can see your ideas realized at a future date.

Next, I call Mr. Robert Fitch Smith, an architect active in Florida. Much of our work with the Florida climate affords us the possibility for speeding up aging and speedier results, and, therefore, I believe that Mr. Smith is in a particularly good situation to tell us about some interesting applications. Mr. Smith.

*MR. SMITH: Ladies and gentlemen, even though I am not going to talk about my first picture immediately, I am going to put it on now and hope that you may enjoy it with me for a bit. It is the interior of a little Florida house, looking toward a translucent panel (See Figure 4.12).

I have listened to many fine and informative talks yesterday and today dealing with the role of plastics in building. To the architect, this detail is good and valuable information as to the parts of future buildings. Since our job is to design complete buildings, we are interested first in the people who will occupy these buildings, because they are our unit of scale; second, in the comfort of these people, the space, circulation, beauty and utility; and then we are interested in how to do the job—the materials, equipment, and so forth.

These viewpoints must form a harmonious unit and must be so designed architecutrally; therefore, a design background becomes necessary in the industrial phase of the work. If your materials, fine as they are, are misused, they will become of less value and will stop progress in its very path. I plead with you to hold to an architecturally-designed product as your goal, instead of a back-yard, do-it-yourself product.

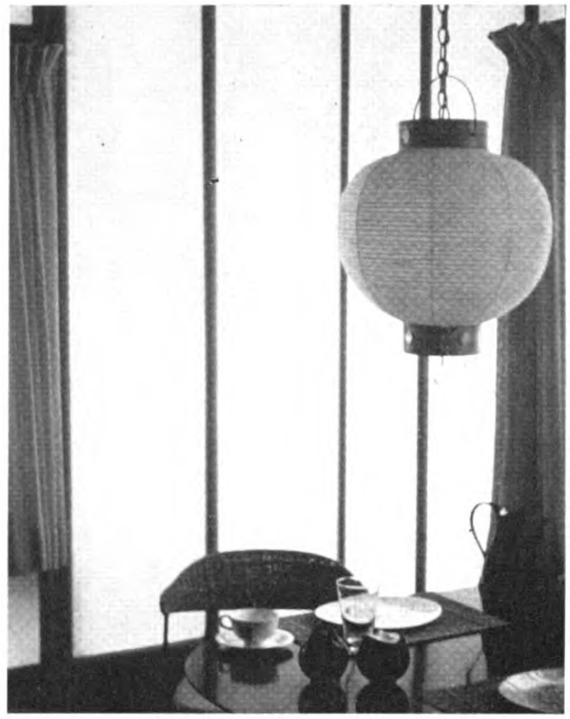

FIG. 4.12: Translucent panel in model Florida home

I think that your big field will be in housing, because you can supply something new which serves far better than the materials with which we have previously built. When the public sees and knows for itself, there will be no question of a future.

What do I mean by the above statements? The small start made last winter in Florida proved much. You may have seen the model of a guest house in the exhibit in the rear of the room. That house really exists. Three years ago my good friend, Alfred W. Russell of the Russell Reinforced Plastics Corporation of Lindenhurst, Long Island, made a visit to my house in Miami bringing with him a group of samples of various types of plastics and fiberglass. As he threw them out on the drafting table he said, "You know, I'd like to be in the building business. See if you think there is a chance."

I was challenged, and I think he was, and so last winter we launched our first venture, the small house. In this little guest house you are seeing the translucent wall which is 3/32 of an inch thick. About 350 square feet of fiberglass are used throughout the little building. There are no dark corners in this building. It's bright and it's happy. When the sun is behind a cloud, the light comes through, and that soft yellow light is beautiful.

Mr. Russell invited 50 architects and their wives to his home in the beautiful setting at Deerfield Beach, Florida, to see the little house. All sorts of comments were made, but I think the most pertinent one came from a woman. She said, "I think it's fine, but when

*Robert Fitch Smith practices as an architect in Miami, Florida, and is consulting architect to the Russell Reinforced Plastics Corporation of Lindenhurst, Long Island, and Boca Raton, Florida. He is a graduate of Michigan State College with an industrial arts degree and has an A.B. and B.Arch. from the University of Miami. He studied special design work at Columbia University and Carnegie Institute of Technology. He taught architectural design for three years at the University of Miami and has designed many buildings in the Miami and South Florida areas. He is a member of the American Institute of Architects, the Industrial Designers Institute, the Architectural League of New York, Beaux-Arts Institute of New York and the Florida Association of Architects.

FIG. 4.13: Expanded fiberglass louvres and fiberglass weave on door.

I am in my negligee I don't care to be on the inside of that fiberglass wall." However, we found that the shadow of a person near the wall was diffused rather sufficiently. Draperies may of course be used, but I don't think they are necessary.

These louvres (Figure 4.13) are expanded fiberglass separating the living room from the little dressing room, just beyond the sliding-type door, which is made of fiberglass basket weave. In the combined kitchen and dining room, the same treatment is used as in the living room area.

I might say that the 350 feet in fiberglass put in this building did not affect the budget set up of the builder. Nor did the use of the expanded fiberglass vents in the louvres running from the ceiling down to the floor. Incidentally, the joint of the ceiling is a very simple, carpenter-made joint. The carpenter had no difficulty in putting up this house.

In Figure 4.14 you see part of the exterior treatment of the house. It is a combination of brick, wood and fiberglass. Mr. Russell thought that for this first venture he'd like some familiar materials, so we used them in combination, and I think people do like that idea. Our next venture will gradually include more fiberglass and a little less of the familiar materials. So much for the little house.

Figure 4.15 shows a business building on Lincoln Road in Miami Beach—a rather swanky spot—which was a remodeling job. In this stretch of building, which is 250 feet long, are eight merchants, who did not want the usual type of marquee. According to the building code, a soft material must be set 16 feet above the line of the walk. Therefore, we had to use canvas along the front, but we did use fiberglass on the marquee itself, the roof and the side panel. We knew that these various merchants, who were selling jewelry, lingerie and women's shoes, and haberdashery, would have to get together on some sort of a new trick for their marquee, so three samples were sent from the Russel plant.

These samples, each four by eight feet, and straw

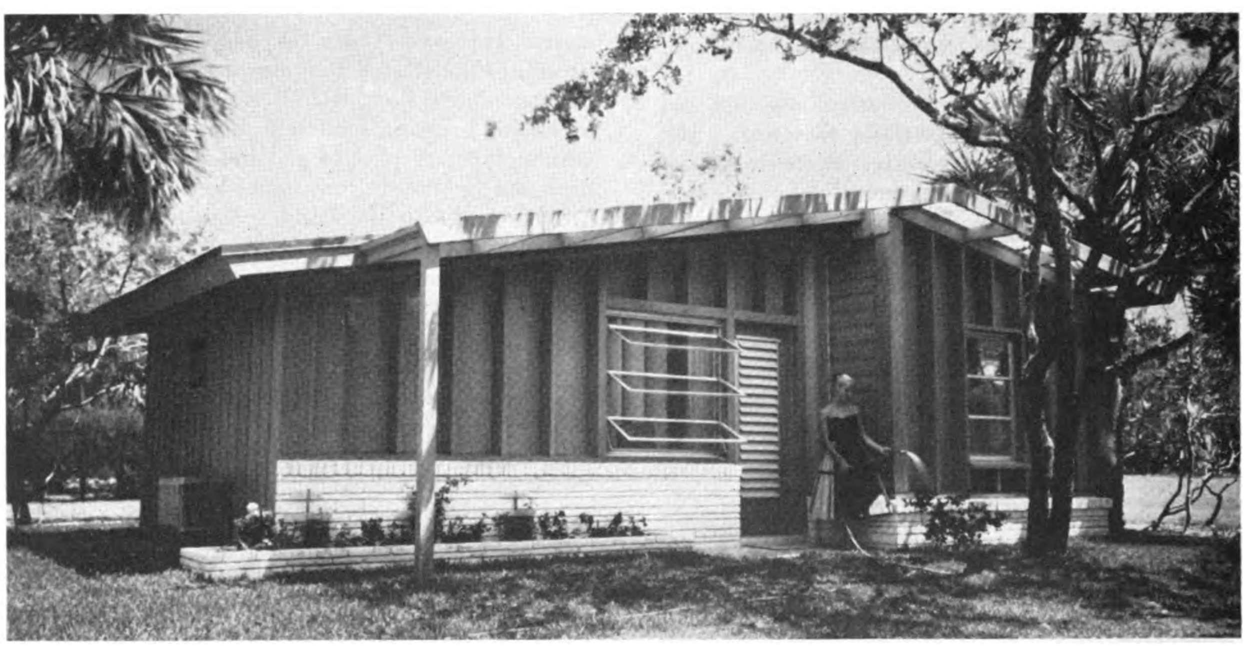

FIG. 4.14: Model Florida home showing part of the exterior treatment

FIG. 4.15: Marquee, side panel and roof are designed with fiberglass installation

colored, were laid on a temporary scaffold at the very height of the marquee. From the three panels with light penetrations of 50 per cent, 32 per cent, and 25 per cent, the merchants unanimously chose the panel that has a light penetration of 32 per cent, and I think that brings us into a new science. If this had been a new building, my design would not have been quite as it is, but in hanging the marquee we had very little structure to work with. Not only is the marquee of fiberglass, but also the upper bend around some second-story windows which were to be blocked out in the new design. The lights up in the overhang, which give a glow through the marquee at night, cast a very soft light on the customers and the buyers (Figure 4.16). In other words, the light coming through, 32 per cent penetration, is complimentary to all of the goods in the windows and very complimentary to those people who want to look like they had a Miami Beach tan.

In one school in Miami, fiberglass has been used in some tilt-up garage doors. Last year the school board allowed me to install four tilt-up fiberglass doors as one wall of a school room. I think we used there a 28 per cent light filtration in a soft green-blue. Above the doors, there is a transom light. The teacher tells me that she loves it. This full wall can be opened out toward a patio, and the children are within or without the area constantly.

So much for my work there. The statement that I'd like to make in closing I have made before, and I should like to make it again after three years of working with fiberglass. Architects have always dreamed of a building material which is free from maintenance, termites, rust, discoloration, disintegration. Now, with the help of new mechanical engi-

FIG. 4.16: Detail showing lights in overhang

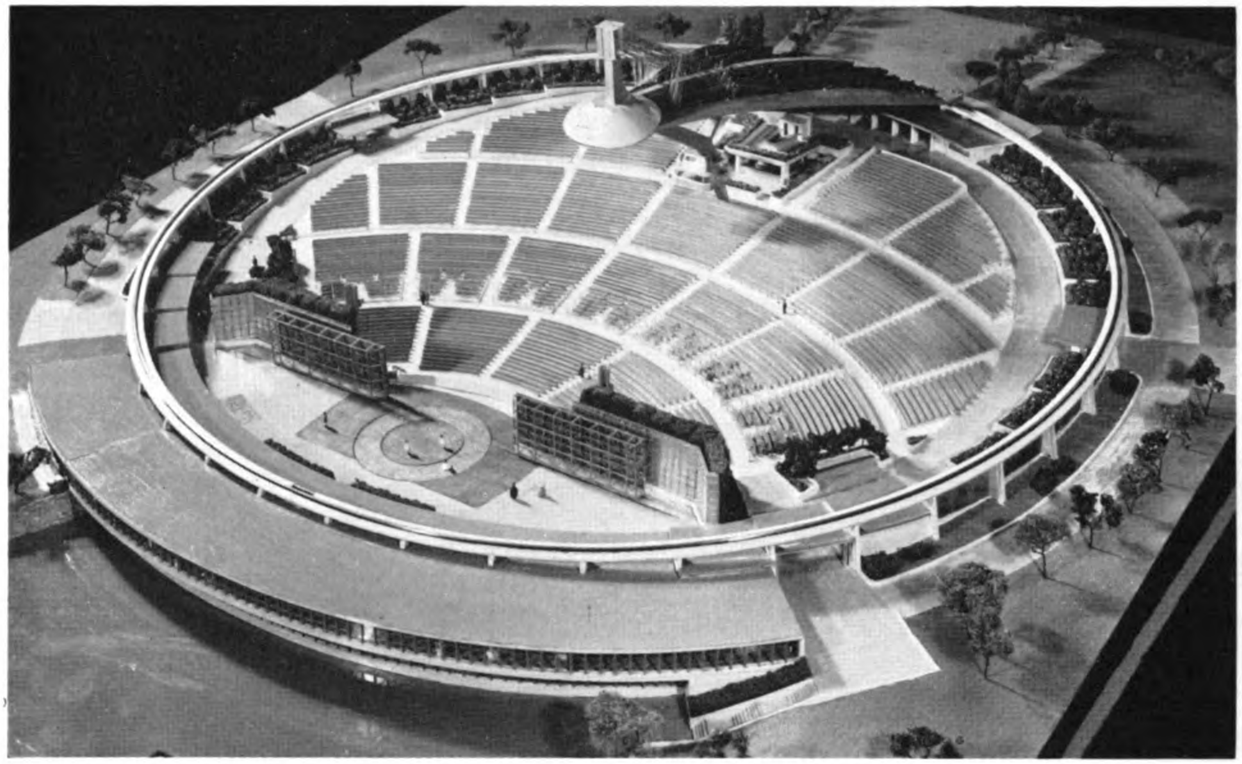

FIG. 4.17: Model of roof for Pittsburgh Civic Opera

neers and industrialists, we may be well on the way to the development of this new material. We may even be on the way toward a new period of American architecture, a bright, new conception for the closed-in spaces where people live—no dark corners, but a happy, sunny material clothed by a good structure. We may even be on the way to the golden age of American architecture. Only our misuse or our lack of appreciation of this glorious new material can slow our progress. Thank you.

DR. BJORKSTEN: Thank you very much, Mr. Smith, for the very beautiful presentation of slides and for your inspiring message.

Next, I will call Mr. Dahlen K. Ritchey, who will tell us about the flexible roof for the Civic Opera in Pittsburgh. Mr. Ritchey is a partner of Mitchell & Ritchey, Architects, in Pittsburgh, and a member of the Building Research Institute. Mr. Ritchey.

*MR. RITCHEY: Ladies and gentlemen, I would like to show you one project from a few years ago. Our Pittsburgh Civic Opera gives summer performances in the Pitt stadium and is rained out perhaps five nights a season. Occasionally the performances get under way, and the people get wet. There are also times when the weather threatens and people don't show up, so that as a business enterprise it is losing.

We, as architects, were confronted with the problem of designing a civic opera where the people could have the pleasure of seeing a performance under the stars and at the same time have some protection quickly available in case of rain.

This is a model of the project, as conceived by Mr. Mitchell. It seats 9,500 people (Figure 4.17). The big boom is a cantilevered steel frame. There is a rink track that goes all around. There are two complete booms on which a 50-horsepower motor is mounted, and these two booms, one pulling in each direction, pull a roof over this structure in a minute and a half. There are 677,000 square feet of plastic roof over this arena.

When time came to develop the material for the roof, we contacted all of the various companies that we could think of—Ringling Brothers Circus and everybody else that was building anything—and we ended up by submitting many of the materials to the Mellon Institute. This brings into mind what Mr. Boyer was saying, that the architects can work with the chemists. The chemists at Mellon Institute worked for a year testing these materials. The materials were put through tensile strength tests, flexual resistance, abrasive resistance, falling, heat and cold, mildew, effects of metal, water, sun, acid, grease oil flammabil-

*Dahlen K. Ritchey is a Partner of Mitchell & Ritchey, Pittsburgh, Pennsylvania, architects. He is a graduate of Carnegie Institute of Technology, Bachelor of Architecture, and has a Master of Architecture degree from Harvard University. He is a member of the Building Research Institute, the American Institute of Architects, and the Pennsylvania Society of Architects.

FIG. 4.18: Roof structure, opened, resembles a parachute

ity and the bonding in case the material had to be patched.

The plastic roof is supported on two systems of cables (Figure 4.18), so that it withstands both outward and inward wind pressure, sort of like a parachute in construction.

The chemists concluded that a vinyl-coated fiberglass was the best material for our purposes. When we first started the project we thought we'd get a material that would probably hold up under our conditions for five years, and it was thought that it would be economically feasible to replace it after five years, but test results indicated that the vinyl-coated fiberglass might last for 10 years.

This project was completely engineered and ready for construction when the Korean war started; we were stopped by that emergency.

We are now working on a sports arena and civic opera combined, for the lower hill section of Pittsburgh. Unfortunately the plastic material is no longer planned for the roof because it has to get year-round usage.

I might add that we got many inquiries about that particular flexible roof—letters from South America, from Wrigley Field for the Chicago team there, and one from British Columbia where a flexible unit of that sort was being considered to protect highly cultivated areas from hail storms.

Now, we had problems, naturally—it was brought out this morning—with the building people in the city. They were very receptive, however, and the special regulations which were necessary would have been put into effect, had the Korean war not stopped the project. We feel very badly that that particular group could not go ahead, but we can certainly see the potential of plastics in making it possible to change the aspect of a structure completely and very quickly. Thank you.

DR. BJORKSTEN: Thank you, Mr. Ritchey. This was a most interesting application, and I certainly hope that we shall see many of your flexible roofs in application within not too many years.

Next I am calling on Mr. James W. Fitzgibbon, who is Executive Vice President of Geodesics, Inc., of Raleigh, North Carolina. Mr. Fitzgibbon will talk about his experience in designing an all-plastic building.

*MR. FITZGIBBON: Ladies and gentlemen, I'd like to speak briefly about an investigation or two that we conducted within the past year in the use of laminated plastics as a total structure, in a fairly sizeable building. There are one or two principles which seem to have evolved during the design and engineering investigation. One is that the conventional structural shapes didn't seem to work too well

*James W. Fitzgibbon is the Executive Vice President of Geodesics, Inc., of Raleigh, N. C. He is a graduate of the University of Syracuse (Bachelor of Architecture) and holds a Master of Architecture degree from the University of Pennsylvania. He was Assistant Professor of Architecture at the University of Oklahoma, Professor of Architecture at North Carolina State College, and formerly was President of Skybreak, Inc. He is a member of the American Institute of Architects and has contributed articles to many architectural publications.

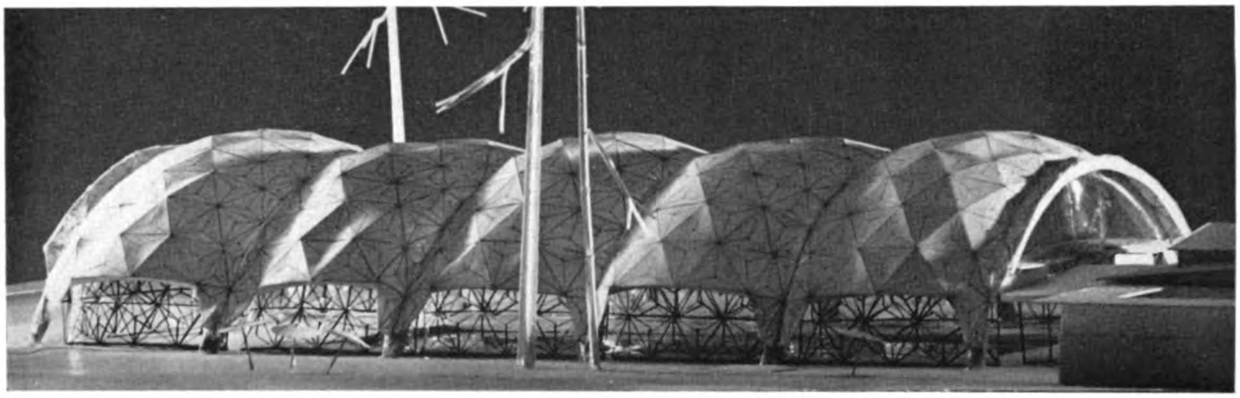

FIG. 4.19: Structural design, model of swimming pool roof

in plastic applications. In particular, the sheet qualities of laminates, and their moldability and formability (starting with a flat sheet and inducing it to a structural strength and structural action by giving it prismatic form by a kind of prismatic corrugation. done by inducing folds and resins into the sheet itself through pressure laminated procedures). We believe that the use of plastics is definitely an industrial use and we are interested in eliminating, as far as possible, handicraft and field activities.

We tackled a proposal from a Southern textile manufacturer for a light construction over a swimming pool that had already been built. The structural design, as in Figure 4.19, was a series of curved, doubled-skinned laminated plastic sheet trusses 72 feet in span. There were five bays, approximately 150 feet in total length. The module is one of the horizontals—a double horizontal unit. Six of those make each bay; 30 were in the entire structure. There are 30,000 pounds of reinforced polyester fiberglass.

The bids on this job included the heating, and we planned to draw warm air up through this double-skin construction, with the skins about one foot apart. The bids came in at around $200,000. The client had $80,000, so the construction is definitely in the future.

It is interesting, however, to note that our first bids on the fabrication of that structure ran approximately $3.50 a pound. Our next bids came in at $2 a pound. Maybe we are getting closer.

I brought along a three-and-a-half-minute film on a series of experiments that we conducted last year indicating particularly the use of sandwich plastics in—I can only call them shelters, I really don't know whether they are houses. This is a kind of shelter which at one phase presents a "turtle back." Introducing a key into the switch of an electric motor opens it up. These are, for the most part, paper models, but I think they indicate a kind of dynamic quality which it is going to be possible to introduce into structures, particularly by utilizing the advantages of the light weight and maneuverability of plastics.

Variously, these structures increase their volumes by approximately twice. They will expand to two, and slightly over two, times the ordinary cubical panel. This was designed as a beach cottage (Figure 4.20). An electric key in the motor operates on top of the central storage unit. This one is cable operated. You get the kiddies out and turn the key.

DR. BJORKSTEN: Thank you very much, Mr. Fitzgibbon, for this very inspiring and suggestive talk.

Next, Mr. George H. Clark will talk to us about the practical considerations in the future use of panels. Mr. Clark is Vice President of The Formica Company, Cincinnati. Mr. Clark.

*MR. CLARK: The most interesting bit of "blue-sky" thinking that has affected me personally is the

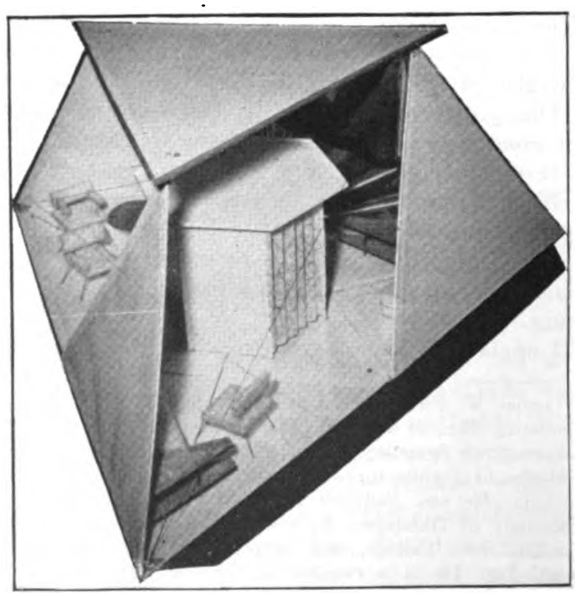

FIG. 4.20: Model of beach cotage

*George H. Clark is Vice President in charge of engineering for The Formica Company, Cincinnati, Ohio. He is a graduate of Massachusetts Institute of Technology with a mechanical engineering degree and has been with The Formica Company for 29 years. He is a member of the Cincinnati Engineering Society, the National Electrical Manufacturers' Association and The Society of the Plastics Industry, Inc.

thinking that landed me a job on this panel. As I look through this audience, I know there are a lot of people like myself who have witnessed the miracles that have happened in this wonderful country of ours in the last 50 years, so I am quite sure that you won't forget the "blue-sky" thinking that you have just listened to. And, there is more on the way.

I am going to give you a shot of "blue sky" and then get down to some of the more practical things with which I am immediately concerned. As long ago as 1928, decorative laminates made a start, but only in 1938 did they make real progress, due to the advent of melamine, and since that time they have grown very rapidly. It might interest you to know that right now between ten and twelve million feet of decorative laminates are processed and shipped, mostly to the building industry, every month.

We are in a very pleasant position in view of the fact that our products are now standardized. It makes it easy for the architect to write his specifications, it makes it easy for the builder to purchase the materials that he requires. Only in this way can plastics that haven't a definite application make progress.

If Gordon Kline is still in the audience, I believe he would agree with me that any product in plastics (or otherwise) that reaches the stage of standardization is always up-graded during the process of standardization whenever products become competitive. I therefore recommend that those from the plastics industry who are listening to me move immediately to provide standards. The fact that products are standardized as to quality does not mean that development stops. The only way to meet your competitor is by making products that are better than standard.

Architects and builders are not likely to use plastic products in quantity unless they are made available; in our industry availability is the watchword. I think I am very close to the truth when I say that there are as many individuals today concerned with the promotion and distribution of the laminated decorative products as are concerned with their manufacture. I hope that won't be always true. This old talk about the man who could build a better mousetrap doesn't click very much with me. My experience indicates that you have to lead your customer by the hand and perhaps pay his expenses, too, before you sell much of your product.

In the meeting yesterday a rather good question was asked from the floor about the finishes or the patterns that are provided by our industry. Some of the finishes that we are now putting out we entered into production almost 20 years ago, and if I never see one of these again, it will be too soon. What I am trying to say is that our customers dictate what we shall manufacture, including imitations. There is always a little resistance to new materials. We make imitation wood finishes the best we know how, because our customers want to make a composite piece of furniture and want the top of that piece of furniture to be a material with the functional characteristics of a decorative laminate. So who are we to tell him that we don't think we should be in the business of making imitation things?

I do recognize that the person who asked the question, who might be a decorator, has a real problem on his hands. If we go back to Hiram McCann's talk yesterday and think of, say, a bathroom, then you would buy floor material from one group of manufacturers, wall material from another, and a shower curtain made by the laminated decorative plastics industry. Up to now we haven't gotten together to the point where a decorator can select a line of complimentary colors.

There is some question of "who is going to take over who" here, but it is true that we have gotten into the domestic structure by the back door. We have made some progress in bathrooms and dining areas. Our materials have been well received by the housewife; the husband and the kids wonder now why they can't have them on the other work surfaces in the dwelling. Our field seems to be expanding tremendously. What we look forward to is very much greater than what we now have. Thank you, gentlemen.

DR. BJORKSTEN: Thank you very much, Mr. Clark.

Now I would like to call on Mr. Max Abramovitz, who is a partner in the firm of Harrison and Abramovitz, Architects, in New York City. Mr. Abramovitz is going to tell us what the architects want, so that the chemists can be guided accordingly in future developments. Mr. Abramovitz.

*MR. ABRAMOVITZ: I am afraid that statement is a little too inclusive. There is no question that the gentlemen who have been on this platform before me do not lack for imagination. I almost feel as if my feet are clay, when I recall what we have seen the last three-quarters of an hour.

Actually, an architect, in a broad sense, wants to enclose space, with the least possible amount of limitation, and we concentrate always from an idealistic point of view of solving the world's problems, anyone's problems, whether they are practical, spiritual, playful, and we don't want to be hampered with any dream child we have got. We have our own theoretical esthetics about how we use materials, and they, frankly, change every year. But, we may use any material

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we can get our hands on, as you well know. We get involved with steel, with glass, and now we are going to talk about plastics.

There is one thing I think I'd like to advise you people to do, this from the experience of having gone through a research program in metals and occasionally one in glass, and that is: Don't think that you have all the answers, but try and find out—and I think many of you do know how—what intrinsic quality your material has and then exploit that intrinsic quality to produce and give us something we haven't got.

I have tried to make a few notes on what I think plastics people have that they might give architects, which we haven't got and which might open doors to us. We are always trying to develop a technique of how to live in our own environment, probably in complete control of everything about us, without having the elements get in our way. I think, fundamentally, what we are trying to do all the time is to get the fine parts of living outdoors, and find some way of keeping that part of the outdoors that we don't like under control. These change according to what part of the world you are living in. The requirements at the equator are different from the temperate zone; requirements in the temperate zone are different from the frigid zone: and these differences impose different problems. I think every one of us would just as soon live outdoors if we didn't feel at times that it was too cold, too wet, or had too much sun. We would like to be free to do and to enjoy what we can.

At this conference I have heard repeatedly of a material you are bringing forth that has the possibility of weighing less than any other material we have used to date. Another possibility is that of continuity. Concentration on those two things will open up a great number of doors from the point of view of imagination.

One of the important points of the brilliant, imaginative little film we saw is that advantage was taken of a material that may not weigh very much and may permit us to do many things we haven't done before. You have a material that can be luminous and can therefore screen and control things beyond what is done today. You have a material that need not be brittle, so that we don't have the problems that frighten us when we think of some of the limitations of glass.

As I said, we spend much time worrying about keeping the cold out and the heat in, keeping the dust and noise out, controlling leaks and controlling light. I know that there are plastics that can, in a film, be applied to a material (or applied to your own material) of a coarser substance than can deflect heat. That, theoretically, might put some of our men who are very seriously concerned about how to use plastics for ducts in the air conditioning field, out of business.

I think you have to keep constantly aware that we are always looking for new ideas. You have to be constantly aware that many of the things you are developing today may be obsolete tomorrow, because technology of all sorts in your own field—among your researchers and among all of your sister sciences—is opening up doors for us.

We talk about all of these mechanical contrivances that control us indoors. We have radiators, we have pipes, we have everything all over and about us. As architects, we find them in our way and we are going to do everything we can to help to find a way of getting rid of them.

If I could build a building that would give me controlled climate without an air-conditioning duct inside, without a pipe, I'd try to build it. We are constantly trying to make the engineers find ways of doing it simpler through technology and science rather than with equipment that gets heavier and more complex.

I think you have a product that may take advantage of what exists in the outer atmosphere about us that, under certain conditions, can be controlled. I know you can take a film of plastic, if I use the word correctly, and put an anode and cathode on it and put heat through it. In that way we create heat, and in another sense we can keep heat from getting onto us. How all of these things can create new forms are possibilities that I won't go into.

When you see an enormous dome, made of a very light material, span a swimming pool, you can turn that into many imaginative ways. When you think of what Mr. Ritchey is trying to do, you can see other great possibilities of dual uses of many things.

We also think about this question of acoustics. We worry about that because noise affects our nerves and makes us unhappy, or uncomfortable, if not properly handled. You have a material that can be soft. There is no material that we have in the building industry that is soft and can do a job for us. If you could develop the quality of being soft, the quality of being translucent or dense, the quality of continuity, and the quality of weight, I see so many possibilities that I think many of the concepts we have today are going to be changed.

When you realize that fundamentally and basically practically everything we build today is rectilinear, I sort of feel sorry for our architects, because how are we ever going to check a set of specifications? I think we are the ones who probably promoted rectilinear lines, because it is an easier method by which to teach people our ideas and tell other people how to check them. Maybe we will have to find some new way of doing it.

There is one other little thought that has come to my mind, that was mentioned to me here, and that is this question of esthetics. Every new material meets resistance from the public. Unless the need is very acute, people are afraid of something new. While you are developing your strong research organizations and looking forward as to how to exploit this new-found material that is just a few decades in bloom, it might be very good to get the creative people—the artists, sculptors and painters—acquainted with and thinking of your material. Many times your material will not be accepted by the public. I know that from practical experience, because we have dealt with two or three metals and some glass material, and we have spent a great deal of time and energy in finding out how to prove in outdoor tests that something can be attractive.

You are probably very fortunate in having a frontier that is doing your experimentation without the discipline of the building codes. I think you ought to watch experimentation in the airplane and ship very closely (designers in those fields have the possibilities of discovering and solving some of these problems for us) while we slowly try and catch up with you and once in a great while can get ahead of you.

And, lastly, it is your industry that has to stick its neck out. You tell us, as architects, to lead you, but we are just small, little people with limited funds. If you have ideas, you should develop serious research programs to find out the qualities of your product, develop your standards, maintain an approach of integrity, and I think we will try to either catch up with you or hope to get ahead of you. Thank you.

GENERAL DISCUSSION

MR. HUNTZICKER: We have just heard a number of the most thought-provoking and inspirational discussions that I think could have been heard at any building or plastics meeting. We are certainly most appreciative to these gentlemen for getting us into the "blue-sky" forest and leading us around for a while.

The discussion and question period will be moderated by Mr. Robert W. McLaughlin, Director of the School of Architecture at Princeton University. He is a graduate of Princeton University and a Fellow of the American Institute of Architects, and a member of the Architectural League of New York. Mr. McLaughlin has practiced as an architect, has been engaged in archeological work and has been Chairman of the Board of American Houses, Inc. He is the author of architectural monographs on brick architecture of Sweden and San Gimignano. He has operated a research laboratory on building materials in Bedford Village in New York since 1940. Even without the rest, that last would impress me. I am sure Mr. McLaughlin is ideally fitted and able to moderate a discussion on the "blue-sky" area of this plastics conference. Mr. McLaughlin.

MR. McLAUGHLIN: This has been one of the best sessions that I have listened to in a long time, and in my work I have to listen to a lot of talk of a rather fair nature. I think this session is particularly interesting and important for the fact that we have combined here the creative elements of two great industries, the plastics industry and the building industry.

The people on this panel come to us with varying points of view but attacking a common problem. When I hear this kind of discussion—the architects being the creative force and requiring high standards of the building and research people, the chemists, physicists and mechanical engineers in the plastics industry—I am convinced more than ever that this fusion of quite different points of view, points of view coming from radically different locations, really makes sparks fly and gets results.

I would say the members of the panel make a million-dollar infield and I hope that the ball will be thrown around very fast. It is a wonderful opportunity.

I have here a question in writing directed to Mr. Fitzgibbon. The writer is unidentified but the question is a good one. Concerning that swimming pool with the fiberglass top, you spoke of having a double panel so that you could heat it if necessary. I assume the panels were to be translucent. What provision did you make for controlling the in-flow of heat to that swimming pool without boiling the water inside?

MR. FITZGIBBON: This was a pool calculated for the borderline area between South and North Carolina. The bottom section of the entire area around that pool opens up and becomes a kind of wind cave to let the breeze through. The curve itself was designed to be drawn off in part, creating a kind of translucent screen over the swimming area. It was not necessary to screen that with an opaque material. We calculated that the heat build-up through that double surface would not be excessive, even in the Southern sunlight.

MR. E. J. DEVLIN (Massachusetts Institute of Technology): First, I'd like to call your attention to the fact that on Page 10 of Issue Number 2, of the BUILDING SCIENCE REPORTER, which is published by Building Research Institute, there is a description of a project we have at M.I.T. on the survey and evaluation of uses of plastics—both present and past uses. If any of you desire to send us information on plastics produced now, we'd like to incorporate it in our study, which includes all types of plastics. We are soliciting your cooperation and we would appreciate your help. My question is for Mr. Boyer. I am an architect, and I know there are a lot of architects here. I wonder if Mr. Boyer would discuss the article about atomic plastics that appeared in the ARCHITECTURAL FORUM.

MR. BOYER: This article in ARCHITECTURAL FORUM was claiming, among other things, that treatment of plastics with atomic radiation could build the strength up equal to that of steel.

You may have realized from Professor Dietz' charts yesterday that there already exists a number of plastics that have the tensile strength of piled steel, particularly in the form of oriented materials. A textile fiber or stretched sample of plastic already has the tensile strength of mild steel of up to 50,000 to 100,000 pounds per square inch, so I can believe that some plastics treated in certain ways in atomic radiation could have the tensile strength of steel. However, if you take just a simple molding of plastic—an ordinary tensile bar of any sort of a molding—and treat that with atomic radiation, the data I have seen does not indicate that you can build the strength up anywhere near that of steel; perhaps a 25 per cent increase of tensile strength. However, Mr. Read from ARCHITECTURAL FORUM assures me that he has the straight dope on that story.

MR. VERNON READ (ARCHITECTURAL FORUM): Yes, the fact is that our information is that tests have shown that the strength property of certain plastics, anyway, is improved by certain irradiation processes. The thing that is controversial is precisely the strength of the plastics. The tensile strength, for instance, is improved by irradiation.

The FORUM's article did not get into the question of degree so much. That was an imaginative article intended to stimulate thinking of what might be done. It was checked at every stage, and the data of it were checked by members of AEC and various other people. They checked every word. They do believe that you can get strength eventually, although they say that that material is not available now. On the defensive, they believe that you can get strength equal to the strength of steel, and on that basis alone the article was written. Of course, Mr. Waidelich and others were invited to comment on what they thought this might do to the building industry in the future, maybe in a generation or two.

MR. McLAUGHLIN: Did you people in the back of the room get that reply?

THE AUDIENCE: No.

MR. McLAUGHLIN: Perhaps I could repeat it. I gather that the article that appeared in FORUM was based on general information of a general nature, indicating a trend that might very possibly lead to the results which I think perhaps many of us took as stated fact, and that the purpose of the article was to bring forth comments from the engineers—who commented. In other words, perhaps the answer is that it is an indication of a trend, rather than a statement of arrival.

MR. FRED MERRITT (ENGINEERING NEWS-RECORD): To further clarify the thinking along these lines, I wonder if a member of the panel or someone in the audience could answer this question: Isn't it true that the irradiation discussed here, namely gamma rays, affects only the electrons, that the electrons are the parts of an atom that normally react in a chemical reaction, and therefore that whatever can be done with gamma radiation probably can be done also by chemical means and probably cheaper?

MR. McLAUGHLIN: Would Mr. Boyer like to pick that one up?

MR. BOYER: Apparently one of the first things atomic irradiation does to a plastic material is to knock out some hydrogen atoms and generate a free radical and odd electrons, and several of these things get together and form a cross-bond. I agree in general with your statement that this may be a difficult and exotic way of essentially cross-linking plastics and that you can cross-link them by many chemical means. Eventually it will boil down to the question of whether this is more convenient and more economic than chemical means of cross-linking.

I'd also like to say that hitting many plastics with atomic irradiation starts a chain of degradation which essentially degrades the plastic right down to liquid monomer, so that this treatment can either completely degrade the material or can build up heat resistance and strength.

DR. H. R. MOORE (U. S. Naval Air Development Center): I think the point that should be made is that of necessity this cross-linking operation is applicable only to the linear polymers or linear plastics or thermoplastics, none of which, of course, has anything at all like the properties of steel. The most you can do by irradiation, by any of these high-energy nuclear-placed particles, is to bring it up to the strength limitations of the existing fiberglass polyester, that is, filled polyester, so that the very most you can do is actually make it. That is, the mechanical characteristics of thermoplastic become the mechanical characteristics of a thermoset. That's just about all.

MR. McLAUGHLIN: I'd like to throw in a question to Mr. Fitzgibbon, who showed as one of the most imaginative and stimulating things I have seen on the screen for a long time. Where do you go from here in your development of that type of structure shown in your movie?

MR. FITZGIBBON: Which one, sir?

MR. McLAUGHLIN: I am thinking particularly of the one that was unfolding.

MR. FITZGIBBON: These are still simply in the model stage. All we need to generate some further action on them is some money.

MISS MARILYN GRAYBOFF (ARCHITECTURAL FORUM): Mr. Fitzgibbon, were any cost studies made on some of those smaller shelter structures, either on a mass-production basis or on unit basis?

MR. FITZGIBBON: We estimated $10 or $15 thousand to produce a model that you could walk into, perhaps 14 feet on an edge, hand-making the sandwich materials and hand-making the joint—the joint is a little catchy.

MISS GRAYBOFF: Hand made?

MR. FITZGIBBON: Yes.

MISS GRAYBOFF: And the cost on a mass-production basis?

MR. FITZGIBBON: I have no idea.

MR. McLAUGHLIN: We have done some other fascinating work which is tied up with Mr. Fitzgibbon's work in North Carolina, and Mr. (R. Buckminster) Fuller has been there with us developing some fold-up, dome-shaped units which a helicopter can, and does, pick up. We have the statement of the Marine Corps for that, and we got into a very interesting combination of what we call the different disciplines. The job of our students was to develop means of folding these dome structures of plastic impregnated cardboard, which is probably not the term I would now apply, so that when the helicopter lifts them, they immediately transfer into streamlined forms. Our students got some quite extraordinary results in the Forrestal Research Center wind tunnel. We begin to think architects are a pretty good clearing house for a lot of these problems.

MR. JOSEPH M. SCHMIDT (Naugatuck Chemical Company): Mr. Fitzgibbon, you mentioned that a budget of $80,000 was set up for the swimming pool structure. Was other material found to meet this client's requirements.

MR. FITZGIBBON: A year ago, when my client saw the bid sheet, he said he'd go to jail before he'd pay that much for a building, (about $200,000) but he has built nothing since. He needs a light structure, one that he can draw, and translucent to transparent in quality. I know he has been fussing around with aluminum frame and glassed-in fills and some devices of this sort, and I know he is going to miss his budget by quite a bit.

MR. S. C. NILO (Rome Air Development Center): Mr. Ritchey, in your example of an amphitheatre for outdoor use you mentioned that a vinyl-coated glass fabric was to be used for the covering. Could you be more specific in describing it? Also, I am interested in learning whether any other materials were considered as satisfactory physically for outdoor use of flexible material.

MR. RITCHEY: There were very many materials tested at the Mellon Institute, and the two that were given the final tests were Vinyon "N" and the vinyl-coated fiberglass. I might add that some of the materials were neoprene-coated fiberglass (black and aluminum backing) and some were vinyl-coated, and the last two materials were the ones that came closest to meeting all the requirements.

MR. JEROME FORMO (Minneapolis-Honeywell Regulator Company): I am interested in knowing whether any of the architects on the panel have quantitative data which might be used in the design of structure for enclosing space, as Mr. Abramovitz suggested, which would completely suggest comfort to the inhabitants of that space. We know from earlier data that such factors as temperature and humidity have been pooled together into what has been known as a comfort zone, and that such factors as acoustical competence and light-diffusion matters, and other factors which I am not aware of, also might be included. Is there any quantitative data available for the ultimate in comfort?

MR. McLAUGHLIN? Max, I think that is directed to you.

MR. ABRAMOVITZ: I think you have hit on something which is very pertinent. Everyone is touching a part, and I don't know that anyone is pulling them all together. Many laboratories are thinking in terms of what they think are acoustical shapes, and I have seen studies that imply at what noise level the human being is comfortable. I know there are quite a few research laboratories working on light, and we know that there are some working on climate. Someone should try and pull them all together, and I think it's something for either the industry or some combined industry. Unfortunately, as we have said, we do not have any institute that weds all the building research together in one particular group. It hasn't been done, and it should be done, by someone who can afford to take the time and the energy. I think it is a very serious and important problem.

MR. McLAUGHLIN: I think that perhaps the closest place to its being done is right here by the Building Research Institute. And I also believe that the profession of architecture is logically the point at which these things do tend, or should come, to focus.

MR. ABRAMOVITZ: The profession of architecture is trying in every honest way. I don't think the architects will get it done unless some rich architect leaves some money to the American Institute of Architects. They keep on talking of a basic organization which will coordinate research, and I think the establishment of one was passed on recently in one of our conventions, but I don't know where it will go and where they will get the money. It's a very important thing to do.

MR. McLAUGHLIN: Our support of the Building Research Institute and the Building Research Advisory Board is the best method I can think of. Now, there is time for one more question.

MR. WALTER TAYLOR (American Institute of Architects): I want to ask about putting human beings in the structure. It seems to me that industry people engaged in this kind of development should, along the way, collect such data before they have effected all of the mechanical details. They should try to get some humans into their structures and begin to collect the data that has been called for in the last few remarks. As Max brought out, there are laws of resistance, and the sooner we can get the ultimate consumer interested the faster we can get along. I'd like to ask Mr. Fitzgibbon if he has put any human beings in these folded geostructures which are so imaginative.

MR. FITZGIBBON: None of these structures that I indicated was anything but a model form. Some of the structures of Buckminster Fuller—and people in association with him—have had minor degrees of use. I can think of two in Canada that are presently in use as small living quarters. In Italy, two complete cardboard structures are, or at least were quite recently, being used as fair buildings, one designed as a small living unit, with one or two other minor uses.

The problem at the moment is to get structures up. As soon as a few more go up, it may be possible to begin other investigations and get people in them promptly, because there are many unanswered questions in our minds regarding these things. (Applause.)

MR. HUNTZICKER: I think the applause indicates the sincere appreciation we have for the excellent presentations which these gentlemen have made to this part of the conference on Plastics in Building. Thank you, gentlemen.

Part V

SUMMARIES OF THE CONFERENCE

FOR THE PLASTICS INDUSTRY:

By Robert K. Mueller*
Monsanto Chemical Company

THE 1954 keynote of the plastics industry was the use of plastic materials for engineering applications. In May, the chemical engineering profession devoted a session of its annual conference to emphasizing plastics as structural materials. The Plastics Exposition, in June, included building materials and a special exhibit featuring a plastic building. In September, the chemists devoted a session of their conference to the theme of structural plastics; the mechanical engineers will conclude the year with a conference on engineering aspects of plastics.

However, this week's full-dress conference on Plastics in Building *is the most significant meeting of the year.* Through the trade associations—the Manufacturing Chemists' Association, Inc., and The Society of the Plastics Industry, Inc.—and in cooperation with the Building Research Advisory Board, experts from the plastics and building industries have been brought together to stress the facts about plastic products and to study their requirements and place in the great building market .

We in the plastics industry want the construction industry to have a true account of the qualifications and potentialities of plastic materials for appropriate uses in buildings. Our industry speakers join me in saying that these two days of discussion certainly stimulate our thinking about the development of plastic building materials, and their qualifications to meet your requirements for structures.

It is in order to make just a reference to two very large volume markets supplied by the plastics industry which were not included in the program—two markets well understood in the building field. They are the paint-protective coatings industry and the plywood adhesive industry.

Colin Clark of Australia, noted international economist, was mistaken when, early this year, he predicted a "rapidly mounting emergency" with mid-1954 seeing a slump in the American economy. As you well know, the construction industry's current "superboom" shows no signs of slackening the rest of this year. September figures reflected a terrible jump in residential construction—12 per cent above August and a towering 53 per cent above September 1953.

The plastics industry is becoming more active in this housing revolution and we hope to increase our participation even more—not only in the housing market but also in other segments of the building industry—through better products and better understanding of building requirements. Contrary to Colin Clark's pessimistic forecast that housing presented no hope for America's faltering 1954 economy because housing costs are too high, the plastic industry affords opportunity for savings in materials and in building methods, now and for the future. We predict that 1954 will see a 20 per cent increase in plastics consumption in the construction market, reaching a total of over 400,000,000 pounds of plastic materials.

SIGNIFICANT ROLE FOR PLASTICS

The trend toward prefabricated building structures and structural elements presents an unusual opportunity for plastic materials. Plastics are capable of revising the "architectural index" of our time. We predict that plastics engineering will play a significant role in a new American style of building architecture because of inherent features of plastic materials and their adaptability in any type of design.

In reviewing the relative delay in development of building materials and methods as compared to these aspects of other industries, a UN housing survey recently made the analogy that if an American automobile costing $1,714 were built with the tools of 1910—as houses in the United States are being built today—its cost would be $60,000. Just as the great advances in machine tools have benefited the consumers of automobiles, so dramatic advances to be made in construction methods and building materials

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will benefit the future building owner and home owner. The stimulus to growth of the American economy which the automobile demand provided in the '20s may well be matched by the increased building demand during the next 10 years. Plastics will be a major contributor.

As a prelude to comments on the individual papers of the last two days, it is of value to compare the plastics industry with the construction industry. I am told that last year the building segment of the construction industry erected structures costing nearly $35 billion, as compared with about a $1 billion gross product for the plastics industry. Twelve per cent of the nation's workers—about 7½ million people—were reported as directly or indirectly employed in the construction industry, in comparison to perhaps one-quarter million persons in our plastics industry. More raw materials were used in construction last year than in any other economic activity—one-third of the copper, one-fifth of the lead, zinc and aluminum, and one-sixth of the iron and steel. This tremendous volume is in contrast to a grand total of three billion pounds of plastics material produced in 1953 for all purposes.

But these distinctions only serve to stress the common elements of the plastics and the building industries. The construction industry is characterized by small businesses—widely distributed, independent and uncoordinated units—much as is the case in our plastics industry. Although there are 52 major raw material suppliers, at least 5,000 different converters, fabricators and makers of plastic products are functioning as separate units in the United States. Most of these are small businesses, each with a handful of employees, and these firms are widely spread throughout the country.

TECHNOLOGIES COMPARED

Another similarity in our industries is the state of technological development. Construction technology has been characterized as "erratic, unrelated by prolific" in a recent study by the Twentieth Century Fund. The plastics industry's technology is in a similar state. In this lies our strength as this fosters development of new economic ways to convert plastics into finished structural materials, but there are also problems for future growth. An important contribution can be made if the building industry will continue to help us determine and define requirements of plastic materials for sound structural applications. This is most important as a guide for the tremendous research and development programs carried on by the plastics industry in an effort to improve its products.

You will be interested in the fact that the output of plastic materials has been expanding at an average rate of about 20 per cent per year since 1918. Ours is one of the fastest growing industries. From 23 million pounds of plastics at the time of World War I, output has jumped to three billion pounds estimated for this year. Output has doubled since 1949 and increased ten-fold over the amount of 1939. The cubic volume production of plastics is now equivalent to the combined production of aluminum, copper, lead and all other nonferrous metals, with the ratio for the next few years predicted to be even greater.

We estimate total consumption of plastics in the building trades for 1954 will be over 400 million pounds. This figure is conservative because of the difficulty in isolating statistics of this nature. But as far as volume of plastics in building is concerned, this is only a starter. Previous speakers have emphasized the characteristics of plastics which justify our estimate of continued industry growth and greater consumption in buildings.

USEFUL CHARACTERISTICS LISTED

As we see it, the characteristics of plastics most useful to the building industry are:

1. Adaptability to shop-made or factory-assembled units which can be assembled and installed quickly at the construction site.
2. Availability of durable, decorative plastic surfaces.
3. Design and construction possibilities of interesting light-transmitting uses for walls and roofs.
4. Availability of flexible and adaptable interior arrangements through designing with lightweight plastic panels.
5. Ability of plastics to resist corrosion, weathering and wear for selected uses in building.
6. The tremendous opportunity for improved and low-cost applications of plastics in the growing usage of mechanical and electrical equipment in buildings.
7. The combination of plastics with conventional materials of construction affords opportunities for a much wider range of desirable structural properties.
8. Safety and cost features in the proper use of plastics are of interest to the building trades for saving time, money and weight.
9. Opportunities for dynamic coloring through plastic materials are of great interest to designers. While the chromatic element is not new in architecture—Egyptian architecture in 7000 B. C. was lavish in the use of color—plastics will allow an economic return to this style feature.

The first two speakers yesterday sought to broaden our knowledge of plastic materials by describing the many kinds of plastics available and how they compare as materials of construction with steel, glass, wood, etc. They reviewed the range of properties which can be expected from today's plastics materials. They highlighted one of the major problems facing our industry, namely—how to advise the architect, engineer, contractor, and the public on what plastics will do and what they won't do. Subsequent discussion revealed that more performance data on plastics are needed to meet considerations of various types of loading, temperature, durability and design. Let me assure you that the laboratories in our industry are already working overtime developing such information, and will continue to do so with your guidance.

You have heard that the major use of plastics in today's building construction is in durable, attractive surfaces for floors, counter tops and walls—applications well established on the bases of sound performance and economy. Decorative malamine panels are broadening their scope of application to include wall paneling in areas where a high degree of durability is required for a decorative surface. Plastic-coated wallpapers and vinyl wall coverings are being developed that bring to the home, office and public building new decorative media with degrees of durability and ease of cleaning heretofore unavailable.

The entry of plastics into the light-transmitting field has given the architect a fresh, uninhibited approach to the problem of letting light into a structure. These new materials enable him to borrow light from one area to brighten another and to control artificial illumination by providing diffused light from a continuous panel source. The lightweight structural independence, almost non-existence of shatter hazard, and unlimited range of colors and degrees of translucency make plastics ideal for light-transmitting uses.

The traditional concept of glazing a light-transmittal panel into a structure is giving way to a combination of the light-transmitting and structural function into one unit—a plastic panel. In an atomic age, this is a factor of major significance in view of recent tests by the Atomic Energy Commission and the Ordnance Department of the Army. Large-scale experiments, i.e., with a nominal atomic bomb, showed that the hazard of flying glass at a distance of seven to eight miles from ground zero was a serious one. Use of plastics in windows reduces this distance of shatter danger to approximately 1.5 miles. A factor of importance in civil defense planning is the fact that, within the area of expected survival, plastic light-transmitting panels virtually eliminate the shatter hazard from an atomic bomb blast.

The use of plastics for piping and ducting is making headway where certain properties are needed and the economics are sound. At the present time, the factors of light weight, corrosion resistance and flexibility appear to control this use. Extensive tests and standardization work are under way to establish performance and dimensional standards for plastic pipe —already a $30 million market.

PLASTICS FOR INSULATION

Plastics have long played an important role in thermal insulation as a bonding agent for glass fibers. Lately their scope of application has broadened considerably with the advent of low-density cellular materials, better known as foams. Styrene, one of the first commercial foams available, is being used successfully in conjunction with masonry construction to provide low K factor at a reasonable over-all construction cost. Plastic films in combination with glass fiber insulation are very effective as moisture barriers. New foams based on isocyanates, vinyl, and phenolic will soon be joining styrene in the construction field.

Structural panels have achieved considerable acceptance in the factory-assembled-house industry. Since the European origin of the prefabrication concept in the late ninteenth century, considerable advances have been made in pre-built stock items for construction and, more recently, in prefabricated buildings themselves. The plastics industry contribution up to this time has been mainly limited to adhesives, but as foams, laminates, and molded nodular units become available on a larger scale, plastics will contribute more. Important advances in architecture and design using startling new concepts of plastics construction are under study at universities and in architectural and construction centers.

You have heard of the major problem confronting our industry in the matter of building codes and in standardization of our products as materials of construction. While some of our plastic materials have been manufactured for 10 or 15 years as standard products, most of them are only a few years old and problems of standardization are yet to be solved. Through The Society of the Plastics Industry, Inc., National Electrical Manufacturers Association and related organizations, plastic fabricators have developed, and are developing, standards that will soon guide the architect and builder in specifying standard plastic materials of construction.

On September 10, 1954 a milestone was passed in the promulgation of building code legislation regulating the use of plastics when the industry presented its concept of a model plastics section to the City of San Francisco for incorporation in its new building code. We hope that this will serve as the basis for future code legislation throughout the United States and Canada.

The future of plastics in building is limited only by our imaginations and the public acceptance of new concepts in living.

We predict that large, lightweight structural panels —made possible by plastic adhesives and foams—will speed construction and provide for flexibility of both interior and exterior arrangements. New style light-transmitting wall panels will lend a spacious air to living areas. Plastic dome-shaped roofs, light in weight, will aid in air conditioning. Durable, decorative plastic surfaces will lighten the maintenance burden throughout. Molded structural units will reduce material and installation costs. Conductive plastic sheeting may bring reasonable-cost radiant heating to the building of tomorrow.

We believe that plastics materials offer an interesting design and engineering medium which the architect and builder can use in ever-increasing amounts for more attractive, more functional structures. The plastics industry has a terrific stake in the trends and growth of the building industry and we intend to contribute in every way possible. The investment in our chemical and plastics industry is tremendous; it is one of the highest of all industries per dollar of sales value or per person employed—about $20,000 per worker.

RESEARCH WILL CONTINUE

We must be assured of outlets for our materials and we are willing to undertake the research and development work necessary to match the requirements indicated by the builders, architects and contractors for plastics in building applications.

The research budget of the chemical and plastics industry is well known as a large one. Some companies spend as much as 5 per cent of sales on research. The industry average is perhaps 2½ per cent. The entire chemical and plastics industry currently foots a bill of about $300 million per year for research. A major percentage of this is going into plastic materials because of the tremendous market possibilities. One of the biggest problems we face is the need for intelligent definition of requirements and specifications for plastics as construction materials. The conference on Plastics in Building has done a great deal for us in highlighting the builder and designer point of view.

I thank you, on behalf of the plastics industry, for this opportunity of meeting you, the representatives of the building industry, and discussing these areas of common interest. We have learned a great deal from you about needs and requirements. The discussions have been most provocative. We hope that, in return, our plastics industry speakers have passed along something of value for you and your industry. Thank you. (Applause.)

FOR THE BUILDING INDUSTRY:

By Harry N. Huntzicker*

United States Gypsum Company

MR. MUELLER gave you his impressions of this conference as a representative of the plastics industry. As a representative of the building industry, I will probably speak for a few minutes with a kind of prejudiced outlook. Mine will be a statement of impressions taken from this conference by someone who is probably prejudiced, because my experience all has been in the building industry.

What are these impressions? I have three major ones:

1. The plastics and chemical people don't know as much about the building industry as they might.
2. Vice Versa.
3. This joint conference is a big step in correcting the first two impressions.

Let me explain some of the points on which we seem to differ. The plastics industry thinks in terms of a few years. It seems like a long time if we think back to World War II with regard to some plastics products, whereas, in the building industry we think in terms of generations. If you compare the two, you then get something in between.

At U.S. Gypsum we get people's confidence by saying gypsum was used by the people who built the pyramids. The Pharaohs were a little bit slow in picking up the plastic resins, and there is quite a difference between a long term of experience with some of our gypsum products and some of the plastic products with which we are going to be working.

I happen to be on the school board in my home town. Recently, I helped rebuild a school building and make substantial additions to it. One problem was to keep the school board from putting in those plastic bubbles. (I have some friends in the plastics industry, too.) Our people wanted to know what the problems were going to be in maintaining these and the plastics people weren't able to give us an answer that satisfied a banker and an educator. We had to take all the skylights out of the present building, and the board couldn't see that this item was a lot different. The final result was that we did not put them in.

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So, there is an inherent danger from incomplete knowledge. The plastics industry will have to solve this problem for the people in the various components of the building industry.

MUST UNDERSTAND DATA

In the discussions on plastics, there seemed to be a lack of familiarity with common building material data and terms. Professor Dietz and some of the other men here are exceptions—professor Dietz, because he studies building materials. You will recall that he compared data on plastics with data on conventional materials, and he didn't do that just as a matter of interest. When he spoke of building materials for a structure, he usually mentioned a number of different materials, all of which have to work together and be compatible. He was thinking of an assembly of many different kinds of materials in one building, all with their own ideas, if you will, of how they will react or move with temperature and humidity changes.

Plastics people will have to learn to speak, not in terms of plastics alone, but in terms of how their materials will work in combinaation with the many conventional materials you will have to use—until you can make these houses entirely of plastics.

We had a discussion of vapor barriers, which I will use as another example. During that discussion no one ever mentioned the *actual* efficiency of polyethylene as a vapor barrier. When we talk about vapor barriers in the building industry, we use standards for vapor barriers and compare different types on the basis of their vapor transmission per unit of area per hour per inch of mercury per vapor difference.

In the building industry today we find that, in order to sell to architects, to builders, to engineers—we must have that type of data, and we also have to give them some data on our experience with it. There are many other angles to the subject of vapor barriers. Sometimes you don't need them at all. Sometimes it depends on what the rest of the structure is and, again, you get back to thinking of your products in terms of completed structures.

We had a discussion on foam plastics for installations. There were no K factors mentioned. We use those only in developing data on conductivity. In any case, I would suggest that you set up some diagrams on density, insulation and costs, so that you can see what areas of the research seem to be most interesting.

Even at two pounds per cubic foot, many of our plastics are not competitive with some of the more conventional materials on the basis of present cost. We in the building industry, I think, would universally get a chuckle out of Mr. Rarig's talk on the New York Board of Appeals.

We make it a practice in our laboratories to develop only a few products at a time. We then start getting approvals from the various code bodies, so that we can give a new product to our markets with the merchandise already approved. We did find that there are some people who cause a little trouble—as you will find in the building industry or the plastics industry—but here is a mode of operation that you will have to learn, just as we building people will have to learn more about the use of resins.

There wasn't a great deal said in this conference about the use of resins for reinforcing present products. A lot can be done to reinforce our present building materials and to improve them by squirting a little resin into them. By using these "juices" recently given to us, we can put a little life into standard products. With paper, wood, or fabric products, there is a considerable opportunity for plastics—and that gives you a chance gradually to infiltrate these industries. You simply can't confront them with an entirely new material; you work upon them gradually, and I think that is essentially one of the things that is going to be done.

What does the building industry know about plastics? I wager that the major building material manufacturers have more people working on plastics than you plastics people have working on building problems. We have done a few things in the plastics business. About half of our interior paint made now is with a synthetic resin binder. We are aware that floor covering and so-called asphalt tile haven't had any asphalt in them for a long time. That kind of knowledge has been with the building industry for quite some time.

I get a feeling from our conference that we need to learn more of each other's language. I sense that the association of the members of The Society of the Plastics Industry, Inc., and the Manufacturing Chemists' Association, Inc., with the Building Research Institute's members is a big step in this direction.

MUST USE PRODUCT CORRECTLY

One of the things we admire is the effort by SPI and MCA to keep people from using plastics where they should not be used. In the building industry, that is one of our greatest problems—to get these products out, but not to have people use them when they should not be used. We understand this, because it is a constant problem for us. We can do much toward helping each other and I would suggest that you consider the activity of the Building Research Advisory Board and the Building Research Institute as a means to this end.

You have been a kind, understanding and intelligent audience. I believe that we share a feeling that this has been a profitable exchange of ideas which should be repeated. It has been a pleasure to work with you. I don't believe we should close this meeting without introducing to you again—and most of you have met him—Bill Scheick, who is the Executive Director of the Building Research Institute and the Building Research Advisory Board. In the building industry, we remember Bill for having been director of the home council at the University of Illinois. He is going to talk to you for a few minutes and adjourn the conference. Thank you. (Applause.)

CLOSING REMARKS

By William H. Scheick, Executive Director
Building Research Institute

BEFORE we adjourn, I want to express my thanks to all who took part in the program of the conference. It has been most satisfying to me, the conference committee members, and to all who helped plan the conference, that it turned out to be so successful. I want to thank, especially, the sponsoring organizations who made the conference possible. I am sure that you all recognize that our speakers were the most authoritative that could be gotten. I want to thank them for their time and efforts, and the committee and sponsors for their help in securing them.

The sponsors made the conference possible; they shared in the expenses. I thank them. And, we can be thankful to the Chamber of Commerce of the United States for allowing us to use their auditorium. We could not have accommodated you at our home base on Constitution Avenue.

I want to thank the audience; your attendance far exceeded our expectations; your interest and attention and your response in the discussion periods helped to make a successful meeting. What really counts, I feel, is that you have come here because of our invitation, you have met many people, you have heard many others—if you want to expand your knowledge you now know how to do that: through the people you have met here, and through the Building Research Institute.

As you leave here, my fondest hope is that you will remember—and tell others—what we are trying to do: Working to create a building science, not a collection or hodge podge of building technology and architecture, but a *Technical Society for the Building Industry.*

Some of you are primarily architects, some primarily engineers, some primarily manufacturers—that first. But remember, you *are* the building industry, and through this Institute of ours we have the way to accomplish what Max Abramovitz was calling for, I believe. By getting together and developing an interchange of ideas, we *can* work for an integrated science.

I would like you to remember that the Institute can do this, and not only at the level of big shows like this one. We like to have some conferences that are at the level of round-table discussions; 30 or 40, or perhaps even a hundred people. We can do that, too. The ideas for our conferences and meetings come from you in the building industry. You know best what your problems are; tell us.

Again, thanks for your attendance. We hope you will be able to attend our next conference. Thank you, very much.

A Discussion of the BUILDING CODE REGULATION of Plastic Building Materials

By S. H. Ingberg

Structural Fire Protection Engineer

Bethesda, Maryland

THE advent of plastics to any considerable scale into the field of building construction introduces a number of considerations relating to safety applying in less degree for other prior uses. These pertain largely to the extent and continuity of the material in a given installation. There is apparent need for evaluation thereof that due precautions be taken to avoid hazardous situations.

The main properties of plastics of interest from the standpoint of fire safety are ignition temperature, heat and products of combustion, and speed of burning or flame spread.

The temperature of ignition, whether determined as a self-ignition temperature[1] or in contact with hot surfaces, is in general higher for plastics than for materials like wood, paper and cotton, the notable exception being cellulose nitrate plastics with very low ignition temperature. The relatively high ignition temperature for most of the others makes for safety in that ignition from given sources is less likely to occur. However, after ignition, the spread of flame may be as rapid as with materials igniting at lower temperature.

The nature of the products of combustion will vary over a wide range but with carbon, hydrogen, and oxygen as the only elements, are not likely to present a toxic hazard beyond what obtains with burning of ordinary combustibles such as wood and paper. However, in interior spaces there can be hazard from increase of air temperature above bearable limits for life safety. With other elements present such as chlorine, nitrogen, phosphorus and sulphur, there may be toxic components in the products of combustion, the hazard of which depends on concentration and the conditions of use of the plastic.

The flame spread characteristics of materials are apparently best defined by the flame-tunnel procedure, based on the progress so far made on this particular. This does not refer to any given type or size of tunnel but to the general method as more nearly duplicating the conditions of flame spread for materials applied as finish on walls and ceilings. For plastics some modifications, particularly in method of support of specimen need be made for some thicknesses but even so fairly meaningful determinations can be made.

The results of ASTM tests for flammability of plastics[2] have not as yet been well correlated with those from the tunnel procedure, even to the extent to which such correlation can be made. There has also developed a diversity in the use of terms. Thus, a material termed "slow-burning" based on a given limit of flame spread in the ASTM tests may come well up into flame spread of over 100 in the tunnel test, depending on properties and thickness. Materials that are self-extinguishing in the ASTM tests may have a range from little or no flame spread in the tunnel test to flame spread exceeding that of red oak at 100. The length burned may give some indications although almost the whole range in flammability indicated above may apply for those that burn only at the igniting source in the ASTM tests.

While the flame-resisting properties of the plastics as such are important, even more so are pertinent requirements relative to application and use. It is probable that fields of fairly safe application in structures can be found for nearly all plastics, except those of very flammable type, if use is conditioned with respect to properties.

The three general fields of use are for outdoor structures and applications such as in signs, for glazing of buildings, and a range in interior uses.

The outdoor use generally presents a minimum of fire hazard. While fires in such installations may occur and partake of the spectacular, little hazard to life and adjacent property is involved with practicable installation details.

Plastics on the exterior of buildings and integral parts thereof introduce conditions not contemplated by present building code requirements which assume wall openings with an incombustible filling such as glass. On account of requirements for light transmission and weather resistance plastics within the combustible range are adaptable as far as serving these requirements are concerned. This requires, however, a new assessment on permissible areas, their segregation, heights of building and of glazing above ground. Present code requirements are far short of providing the necessary safeguards of these particulars.

The conditions for the roof location are different from those for the wall openings in that ignition from the exterior by radiation or convection of heat is less likely, and with proper slope and thickness of glazing the probability of ignition from flying brands can be minimized. If ignited by a fire in the top story, little will be added to the fuel for the fire. Hence with limitation on individual glazed areas and segregation of areas the conditions would be not far from what is attained with conventional details, assuming no plastic of the highly combustible type. The exception would be where full protection of exterior openings is desired, such as against conflagration conditions.

For interior uses the regulations for interior finish may apply in part. Such requirements in building codes are relatively new and much remains to be learned from both testing and fire experience, with the latter at indeterminate cost. Here there is interest in the nature of the products of combustion where there is less or none thereon for exterior uses.

Hence for achieving a desired degree of fire safety in the use of plastics for building purposes some use can be made of present building code requirements although they are severely limited in the extent to which they apply, inclusiveness, and the experience had with the newer types of requirements. An adequate basis of experimental determinations is required with incorporate testing details representative of the installation conditions for the plastics. Thus in time can be served not only the purposes of safety but also those concerned with a stable and continuing demand in this field for the products of the industry.

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[1] A method and apparatus for determining the ignition characteristics of plastics by N. P. Setchkin. National Bureau of Standards Journal of Research 43, RP2052, Dec. 1949.

[2] 568-43. Method of Test for Flammability of Plastics 0.050 in. and under in thickness.

635-44. Method of Test for Flammability of Plastics over 0.050 in. in thickness.

A Report on

SPRAYED-ON PLASTIC SHEETINGS

By Guy G. Rotherstein

Architectural Consultant to Liquid Plastics Corporation and Progressive Industries, Inc.

THIS is a brief report on the recent developments of site application of unprocessed plastics. Under this concept the plastics are used like other building materials and are applied on the job with the appropriate tools.

The type of plastic which, up to now, is the most developed for such uses is a vinyl cholride-vinyl acetate copolymer known as Plastispray. This material is brought to the site in a liquid form and the tool used for its application is a spray gun working with 60 to 80 pounds of pressure.

The plastic is applied in thicknesses varying from 20 to 40 mils. It cures chemically as soon as sprayed and forms a flexible sheeting with a tensile strength of over 1000 pounds per square inch and maintains an elongation factor of over 200 per cent. It can be applied to surfaces made of almost any material and has an adhesion of 10 pounds per square inch, or more. This material lasts the normal lifetime of a building, with minimum maintenance.

The most remarkable aspect of this plastic is that, applied to a structure, it forms a continuous sheeting, or "skin," of any size or shape, following all the movements of the structure. To me, as a designer, this means that we have finally found the answer to the age-old problem of the *joint* in construction. The full impact of this event means a complete change of almost all concepts of our present-day construction technology.

Designing with sprayed plastics affects structure, mechanical systems (including heating and air conditioning), the selection of materials, the assembly of materials, and color schemes.

Some of the significant uses of sprayed plastics, made up to now, are:

1. Covering all exterior vertical surfaces and horizontal projections of a new 15-story concrete hotel in Tyler, Texas. There are no flashings, copings, facias, or veneers and caulking. The entire structure is enclosed in a colorful plastics. Also, in New York the Lever House has the stucco soffit, under the open part of the building, covered with a jointless sheet of approximately 15,500 square feet of sprayed-on plastic.
2. The same material is used as a wall covering over plaster in the New York University Medical Center. The sheeting forms a washable and abrasion-resistant skin that has no joints or seams. Also, this material is similarly used in schools and in a New Jersey school it has been applied directly on cinder block for greater economy.
3. Another major use is in the roofing of large areas of complicated shapes. Here. the plastic is applied to various kinds of materials such as concrete, metal or fiberboards. Recently, the dome of the New York Central Building was re-roofed with sprayed-on plastic.
4. These materials also are used as vapor barriers, giving maximum performance when applied without joints to the inner surface of walls or roofs.

Architects and designers are developing further uses of this material and taking advantage of its inherent economies. These developments are most exciting and the young industry of sprayed-on plastics is moving very rapidly on the basis of its own merits. Up until now, none of the larger plastic or chemical companies has actively participated in this development.

ATTENDANCE AT THE CONFERENCE

Abramovitz, Max, Partner, Harrison & Abramovitz, 45 Rockefeller Plaza, New York, New York

Achhammer, Bernard G., Assistant Chief, Organic Plastics Section, National Bureau of Standards, Washington, D. C.

Adams, C. Howard, Group Leader, Research, Monsanto Chemical Co., Springfield, Massachusetts

Adams, Paul L., Vice President, Carr, Adams & Collier Co., Dubuque, Iowa

Ahern, Frank L., Chief Safety Officer, National Park Service, Interior Building, Washington, D. C.

Aikman, W. F., Engineer, Owens-Corning Fiberglas Corp., Toledo, Ohio

Alfero, John B., Materials Engineer, Bureau of Ships, Department of the Navy, Washington, D. C.

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